A study of factors influencing consumer preference for certain beers with particular reference to flavour.

Pierson, B J

A STUDY OF FACTORS INFLUENCING CONSUMER PREFERENCE FOR CERTAIN BEERS WITH PARTICULAR REFERENCE TO FLAVOUR

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BARRY JOHN PIERSON

Queen Elizabeth College,

University of London

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ABSTRACT

Increased demand for cask conditioned beer in recent years has suggested some degree of differentiation by the consumer between this type of beer and brewery conditioned beer.

Differences in flavour between the two types of bitter beer were determined using a trained panel. A vocabulary of descriptive terms for odour, flavour-in-mouth and after-taste was developed. The beers analysed differed significantly in terms of several qualities and the relationships between these were established using factor analysis. In this way all the odour, flavour-in-mouth and aftertaste qualities were reduced to nine, eleven and ten factors respectively. Nested analysis of variance identified significant differences in terms of these factors between the individual beers and also between the two beer types.

Preference data with regard to the flavour of selected beers were obtained from a sample of consumers, using preference tests; survey techniques were used to obtain social and other data relevant to drinking habits. A preference was shown for brewery conditioned beer with respect to both odour and taste. The ability of the consumer to define flavour differences and express these in terms of a meaningful vocabulary was investigated, and it was shown that 76% of odour terms and 77% of taste terms used by consumers as reasons for their preferences could thus be classified. The results obtained (and also those from the consumers' assessment of certain pre-selected flavour qualities) were related to the descriptive data obtained from the trained panel. By means of multiple regression analyses, significant explanations of preference variations were possible in terms of flavour differences identified by both the consumers and the trained panel.

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For reasons of confidentiality no single brewing company has been named in this research but the help and co-operation of staff of the many breweries I visited proved invaluable and is gratefully acknowledged.

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I am not certain whether this thesis would have been completed without the constant support and encouragement of my late mother and my wife Sharon; this work is therefore dedicated to them.

DEDICATION

This work is dedicated to my wife Sharon and to the loving memory of my late mother, for their constant love and support.

TABLE OF CONTENTS

	Page
Title	1
Abstract	2
Acknowledgements	3
Dedication	4
Index	5
Introduction	6
Aims of Project	17
Part I - The Laboratory Panel	18
Introduction	18
Experimental	18
Results and Discussion	30
Part II - The Consumer Survey	65
Introduction	65
Experimental	66
Results and Discussion	87
Summary and Conclusions	174
References	182

INTRODUCTION

Beer has been defined as "the liquid product of the alcoholic fermentation of a wort prepared wholly or mainly from cereal-derived raw materials and sugary raw materials, yeast and drinking water, with or without the addition of hops or bitter materials derived from hops and which contains not less than 2% of alcohol by volume at 20°C".[1] Many types of beer are currently produced in the UK, bitter beer being the most popular form of draught beer.[2] The popularity of this type of beer was already well established by 1851 (when it was usually referred to as pale ale),[3] although the alcoholic strength and hop content were undoubtedly greater than that of ordinary bitter produced today.[4] In todays' market there is direct competition between two main types of draught bitter beer, those conditioned in the barrel or cask and those conditioned in the brewery in bulk. The main stages of the development of this market situation will now be discussed.

With the invention and application of scientific instrumentation in the late eighteenth century[5] and the discoveries of Pasteur in the mid-nineteenth century,[6] the brewer increased his understanding and control of the brewing process. With this added knowledge the brewer has constantly sought methods to increase the stability and shelf-life of beer. The development of the bottling industry in the late nineteenth century[7] and the increased use of chilling, filtration, pasteurisation and carbonation techniques in the early part of this century,[8] gave the brewer a stable, bright, conveniently packaged product in the form of bottled beer. The

increased stability and convenience of beer in this packaged form allowed the larger brewers to distribute their product over a wider area. Gradually a small number of brand names emerged to become the first examples of "national beers".[+] By 1939, sales of bottled bitter beer (pale ale) accounted for 30% of the beer consumed in the UK[10] and this popularity continued well into the 1950's, by which time a relatively small number of heavily advertised national brands of pale ale had become sufficiently well established to suggest a movement away from local draught bitter beers towards the more uniform bottle product.[11]

In the early 1950's the bitter beer market was shared between draught bitter beer and the bottled equivalent, pale ale.[12] At this time, draught bitter beer was still mainly produced traditionally by racking into barrels (or casks) where the secondary fermentation or conditioning would be encouraged by the addition of priming sugar.[13] The ultimate quality of this beer, as perceived by the consumer, relied considerably on the skill of the individual retailer[14, 15] (publican or cellarman) and beer quality therefore varied between retail outlets. Furthermore, as the beer was removed from the cask, air was drawn in, and this encouraged chemical and microbiological changes which in turn resulted in flavour changes in the beer.[16] The quality of such beer would therefore vary throughout the life of a single cask. Conversely the quality of bottled beer was largely determined by the brewer and the consistency of flavour and appearance in the smaller packaged units was greater.[17] Brewers have since claimed that the

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[+]Probably the best known example is that of Bass Pale Ale which, in 1875 was given the first ever registered trade mark for its now famous red triangle, which is displayed on the label of its bottled pale ale.[9]

characteristics sought in a bottled beer are "... brightness, sparkle, a clean palate and reliability, the knowledge that the quality of a particular beer is unlikely to vary from one pub to another".[18]

The ultimate aim of the brewers of transferring the advantages of stability and convenience from the restrictions of the bottled product to the draught commodity was apparent as early as 1864,[19] but it was not until the early 1930's that this became a commercial reality.[20] The stabilisation process applied to draught beers involved some or all of the stages of filtration, carbonation and pasteurisation.[21] Unlike traditional bitter beer, which is conditioned in the cask, (hence cask conditioned beers, CC beers), the stabilised product is conditioned at the brewery in bulk (hence brewery or bulk conditioned, BC beers), often by "artificial carbonation" at low temperatures to facilitate solution of the CO_2.[22] Whereas CC beers rely for their effervescence on gaseous CO_2 produced during continued natural fermentation in the cask, BC beers are artificially carbonated and filled into metal "kegs" under gas pressure at the brewery. This difference between CC beers and BC beers is further emphasised by dispensing methods used at the retail outlet where CC beers are delivered from casks by gravity or by the use of simple pumps and BC beers are served under pressure of CO_2,[23] often with additional chilling to help keep the gas in solution. It may therefore be concluded that BC beers possessed the desirable characteristics of bottled beer (viz brightness, sparkle, a clean palate and reliability) [24] whilst the draught beer had the added advantage of reduced transport and handling costs of the larger containers.[25]

A number of BC beers had been introduced into tied houses as draught national brands by the mid-1950's and the draught form of

this beer type rapidly gained popularity at the expense of its bottled counterpart.[26] This introduction of BC beers compounded the financial problems of smaller brewing companies often already unable to meet the expensive capital outlay of bottling equipment and promotion costs.[27] The advantages offered by the stability and convenience of BC beers expanded the distribution areas for draught national brands to the brewing companies who could afford to produce these beers.[28] Similarly the increased level of advertising of a relatively small number of national brands had a noticeable effect on consumer demand for such products to the detriment of locally brewed CC beers.[28] These advantages undoubtedly assisted the progress of the larger brewing companies (while hastening the demise of the smaller companies) during the acceleration of concentration in the brewing industry in the 1960's.[28, 29] With the take-over of small breweries, whose production was often devoted solely to locally distributed CC beers, the number of CC beer varieties rapidly decreased during this period.[+] Although it has since been claimed that the introduction of BC beers was not intended as a replacement for CC beers but merely as an addition to the product range,[31] by the early 1970's it appeared that the once wide variety of locally brewed CC beers would be entirely replaced by a small number of nationally branded BC beers.

This situation was viewed by many beer drinkers as a restriction of choice, and consequently a growing concern was organised into a campaign to protect "real ale" or CC beers.[32] This campaign, CAMRA (the Campaign for Real Ale), created a considerable awareness of the

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[+]Between 1966 and 1976 the number of different beers on sale in the UK is reported to have decreased from 3000 to 1500.[30]

loss of choice and the claimed undesirability of pasteurised, pressurised BC beers and ultimately made an impression on both beer drinkers and brewing companies alike.[33] So successful was this campaign that many large brewing companies, who had previously reduced or phased out their production of CC beers, began to promote them and even brewed new varieties.[32, 34] The smaller breweries whose very existence had been threatened, also benefited and have now formed a stable and significant minority share of the beer market.[35]

The campaign was centered around bitter beers and the platform was based primarily on perceived sensory differences between BC beers and CC beers.[36] It was claimed that BC beers as a type were bland, a quality reported to result, in part, from artificial carbonation and chilling prior to dispensing.[37] Not only were CC beers considered by campaigners to possess a greater intensity of flavour but also a wider range of flavour qualities[37] resulting perhaps from the many variations in brewing techniques of the few remaining local brewing companies.

In a scientific project, such as this, the opinion of CAMRA supporters may be regarded - possibly rightly so - as being of little consequence. However, further substantiation of this claim appears in a more refined distinction between the two types of bitter beer recently made in a report of the Foods Standards Committee, who stated "the keg beers (BC beers) found ready acceptance among those seeking a blander, sweeter and less bitter drink than the traditional product (CC beers)".[38] Additionally, scientific research has demonstrated a lowering by CO_2 of the perceived intensity of a number

of flavour compounds in beer.[39]

Such claims relating to flavour differences between the two beer types have not been substantiated by any form of objective sensory analysis; instead they are often based on subjective and even emotive accounts. Over recent years, techniques of descriptive sensory analysis have developed on a sound scientific basis and can be used to describe and quantify differences in sensory properties of foods in a relatively objective manner.[40] Such methods have already been applied to a wide variety of foods and drinks, including coffee,[41] cooked beef,[42] oysters, clams and shrimp,[43] and whisky.[44]

This analysis relies upon unbiased quality assessments by highly trained assessors, communicating in a common language and then assigning intensities to their perceived sensations in a reproducible manner. In the case of the descriptive analysis of flavour, the technique is unfortunately complicated by the lack of a standard language or vocabulary of flavour qualities[45], - odour descriptions in particular. Recent attempts by Harper et al. to develop a classification of odour quality terms, which could be applied to descriptive sensory analysis of food in general, produced a list of 44 odour qualities.[46,47] However, since odour plays such a crucial part in the overall perception of flavour,*[48] it is often necessary to select terms which are specific to the particular commodity being assessed.[50] Because of this specificity, detailed vocabularies have been proposed for certain commodities, for example,

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*Flavour has been defined as:- The combination of taste and odour. It may be influenced by sensations of pain, heat, cold (e.g. spices, horseradish and menthol) and by tactile sensations.[49]

cider and perry[51] and apples,[52] in the expectation that they will be accepted as standard terms for that commodity. In this way it is hoped that communications between researchers, in terms of flavour qualities, will eventually improve so that direct comparison of inter-laboratory results is facilitated. To further this aim a sub-committee of the International Standards Organization was established in 1968 and produced a draft standard of essential terminology relating to the sensory analysis of food flavour.[53] In addition to a British Standard glossary of terms relating to the sensory analysis of flavour,[54] three parts of a series of International Standards have also now been issued, dealing specifically with recommended vocabularies for sensory flavour analysis.[55-57]*

It so happens that the area in which this vocabulary development and standardisation is most advanced is in the sensory analysis of beer. This work was initiated in 1975 by Clapperton and Meilgaard who attempted to record, rationalise and classify terms then reported in the literature to describethe flavour qualitites of beers.[59] This first publication, a proposal for discussion, followed discussions of the Joint Working Party of the American Society of Brewing Chemists and the Master Brewers Association of America, together with an informal flavour group in the UK. Subsequent modifications have resulted in several versions of this system of terminology in 1976,[60] 1977[61] and culminating in the currently recommended terminology.[62] This current system comprises 44 terms intended to enable researchers to communicate effectively and in a

*A fourth part of this series has now been circulated for discussion.[58]

standard manner about beer flavour. These "first-tier terms" are then sub-divided to give 78 additional terms ("second-tier terms" and acceptable synonyms) used to define each separately identifiable flavour note in beer.[61]

e.g. Class	First-tier term	Second-tier term	Comments & Synonyms
17	Burnt		Scorched aroma, dry mouthfeel and sharp acrid taste.
		17.1 Liquorice	
		17.2 Bread-crust	Charred toast
		17.3 Roast-barley	Chocolate malt, chocolate-like.
		17.4 Smoky	

Although flavour qualities have been proposed for other foods, this is the first vocabulary to be presented and accepted internationally. (Incidentally, this is not the first instance of brewing research pioneering in the application of sensory techniques, as shown by the early use of simple difference tests in the brewing industry by Helm and Trolle in 1946).[63] Descriptive sensory analysis of beer flavour employing this proposed vocabulary has already been reported by Brown and Clapperton in a study of terms used to describe ale flavours.[64]

Despite the development of this vocabulary and its translation into six European languages,[64] there has been some reluctance to correlate objective sensory measurements (from trained laboratory panels) with the more subjective preference assessment made by consumers. This is not surprising and is probably due to the inherent difficulties of collating reliable and reproducible data from consumers. Several reasons account for this; for example some

consumers are unable to give articulate reasons for their likes and dislikes, some suffer from failure of memory recall, some are unaware of factors which influence decision-making and some are biased by imagination.[65]

Whilst efforts have been made to ascertain the consumer's awareness of texture in food systems[66,67,68] equivalent investigation of the flavour of food and drink has not received the same attention.

Some workers have identified potential problems in such investigations. For example confusion between identification of the basic tastes, sour and bitter, has been demonstrated using untrained assessors even in the controlled environment of a laboratory.[69] Descriptive words have been shown to have variable meanings when used by consumers to describe reasons for preference for the flavour of wines.[70] Consequently, while preference analysis is now well established, using such methods as hedonic rating scales,[71] the value of consumers' description of their perceived flavour sensations remains largely uninvestigated, yet highly important.

Some workers have attempted to explain variations in preference by relating data from objective sensory analysis directly with hedonic measurements.[72-75] The majority of these studies however, have been concerned with food texture and the feasibility of applying such methods to flavour has not been fully tested.

Some published examples of the analysis of consumer acceptability of beer have attempted to determine the relative importance of pre-selected flavour qualities to a stated preference.[76-80] A graphic semantic profile was proposed in which consumers rated beers using eight pairs of antonyms on a 7-point scale.[76] The paired terms

included some which were subjective (e.g. filling/not filling) and some which maynot have been within the understanding of the average consumer (e.g. aged/green). A study of the influence of beer brand indentification on taste perception used nine specific qualities which had already been shown to have a level of meaning to consumers.[77] When the level of one specific flavour quality is responsible for the familiarity of a beer to consumers, it is obviously important to insure that the level is correctly maintained. In one particular case the quality was bitterness and the problems of its assessment by consumers were reported.[78] Other workers have shown bitterness to be directly related to acceptability.[79] In a later study, bitterness was thought to be an attribute which would be understood by consumers without training and in this instance, beers were rated by consumers for bitterness and three other qualities using linear rating scales.[80] In these instances little attempt was made to assess the ability of the consumer to recognize any of the pre-selected qualities, and in a number of cases, qualities which would have little meaning to a consumer were included. There is no instance reported in the literature where preferences for beers were directly related to objectively determined sensory differences.

Therefore, in the absence of the basic methodology necessary to interpret descriptive data from consumers it is hardly surprising that the effects on trends in preference of largely unsubstantiated flavour differences between BC and CC beers have remained uninvestigated. What is perhaps surpising however is that despite current interest in beer flavour research (as shown by recent publications), e.g. [59-62, 84-86], no attempt has been made to correlate

objective flavour differences, as perceived using the human senses, with consumer preferences.

This research was designed to investigate this neglected area.

AIMS OF THE PROJECT

1. To define objectively and to quantify flavour differences, as perceived by the human senses, between BC and CC beer types. This is described in Part I of the thesis.

2. To determine any consumer preferences in the odour and flavour of beers selected to represent the two beer types and to assess the ability of consumers to provide reasons for preferences, in terms of their own flavour descriptions. This is described in Part II of the thesis.

3. To attempt to explain any consumer preferences in terms of the objectively determined flavour differences. This is also described in Part II of the thesis.

PART I - THE LABORATORY PANEL: DESCRIPTIVE SENSORY ANALYSIS OF BEERS.

Introduction

In order to achieve the first aim of this project (see p 17), it was necessary to train a panel of assessors to recognise and analyse flavour qualities of beer. A multistage programme was introduced with the objectives of developing a standard vocabulary of flavour qualities and establishing a method of assessing the intensity of each quality. Once these objectives had been achieved, techniques of descriptive flavour analysis were used to determine the nature, extent and significance of any differences in flavour qualities of selected beers and beer types.

Experimental

The materials and methods used are described under the following headings:-

Selection and training of assessors.

Selection and use of a reference beer.

Selection, storage and presentation of selected beers.

Analysis of selected beers.

Selection and training of assessors

A pool of 22 potential assessors comprised 7 females and 15 males with ages ranging from 19 to 50 years, all of whom were regular employees of this establishment. All assessors first participated in 3 tests recommended by A.D. Little Inc., including (a) identification of the 4 basic tastes using coded solutions of 2% sucrose, 0.2% sodium chloride, 0.07% citric acid and 0.07% caffeine.

(b) ranking 4 sucrose solutions of concentrations 2%, 5%, 7.5% and 10% in order of sweetness intensity and (c) odour descriptions of 20 reference compounds.[81] This procedure was used as a preliminary exercise to introduce assessors to the techniques of sensory analysis and was not intended as a screening process as recommended by some other workers.[82, 83]

When this research began in 1975, some vocabularies of flavour qualities had been published, each with varying degrees of relevance to the sensory analysis of beer. These included work in 1972 by Wren[84] and the early work in 1973[85] and 1974[86] by Clapperton, both of which were directly concerned with beer flavour. Vocabularies of flavour qualities for commodities related to beer included those of Williams on cider and Perry in 1975,[51] whilst a general vocabulary of odour qualities had been proposed by Harper et al. as early as 1968.[46, 47] A study of these references together with private communications from members of the Brewing Industry,[87-90] provided a preliminary list of 280 descriptive qualities that could be relevant to beer flavour. By eliminating some of the very obvious synonymous and superfluous terms and grouping some of the remaining qualities, a secondary list of 88 qualities was produced. (see Table 1, p. 20). A panel of 6 assessors further reduced this list by assessing the relevance of each quality term to a wide range of beers which they analysed for (a) odour (b) flavour-in-mouth and (c) aftertaste. During this assessment the secondary list was reduced to 63 qualities and 12 new relevant qualities were introduced, giving a tertiary list of 75 qualities which are underlined in Table 1, page 20 . These were then arranged according to their

Table 1. Secondary list of 88 flavour qualities applicable to the descriptive sensory analysis of beer

Almonds (46,47,85)*
Ammonia (46,47)

Bitterness (Immediate) (85,86)
Bitterness (After-taste) (84,86)
Bread-like (51,85)
Burnt/Roasted (88,90)
Burnt rubber

Camphor (46,47,85)
Caramel (51,85,86,87,88,89,90)
CO_2 tingle (85)

Cardboard (51,85,87,88,90)
Catty (51,85,89)
Cheese-like (85)
Clean (no mouth coating)(51,85)
Cooling (46,47,85)
Cut-grass (46,47,85)

Diacetyl/Buttery (46,51,84,85,87-90)
Dry (46,47,85,86,88,89)
Dusty (85,88)

Earthy (46,47,51,85,86)
Estery (84-90)
Etherish (46,47,85)

Faecal (46,47,85)
Fishy (46,47,85)
Floral (46,47,51)
Freshly fermented (85)
Fruity-citrus (46,47,51,85,86,89)
Fruity-other (46,47,51,85,86,89)

Goaty (85)
Grainy (85,87,89)
Gravity fullness (85,90)
Greasy (85)

Herbal (46,47,51,85)
Honey (51)
Hop bitterness (90)
Hop fragrance (85)
Hop oil (85)
Hydrogen sulphide (51,85,87,89,90)

Malty (84,86, 88)
Malt syrup
Mealy (85)
Meaty (cooked) (46,47,85)
Metallic (46,47,84,85,87-90)
Mousey (51,85)
Mouth-coating (85,86)

Nutty (85)

Oxidised (84,85,87-90)

Paint-like (46,47)
Peppermint (46,47)
Phenolic (51,85,87,89)
Primings (89)
Pungent (46,47,85)
Pyridine (47)

Over-cooked Cabbage (DMS) (46,47,51,84,85,87-90)
Onions (46,47,51,85)
Garlic (46,47,85)

Rancid (46,47,51,85)
Raw (46,47,85)
Resinous (46,47,85)
Rotten-outrid (46,47)
Rubber (51,84,85)

Salty (85,87,90)
Sharp-acidic (46,47,51,84-89)
Sickly (46,47,85)
Slimy
Smoky (46,47,85,86)
Smooth (46,47,85,86)
Soapy (46,47,51,85)
Sour grain (85)
Sour milk (51,85)
Spicy (46,47,51,85)
Starchy (85)
Straw-like (85)
Sulphur dioxide (51,85,87,88)
Sweet (46,47,51,84-90).

Thin (85,89)
Tomato Plants

Vanilla (46,84,85,88)
Viscous (85)

Warming (46,47,85)
Wet dog
Wet grain (85)
Winey (85)
Worty (85,86,89,90)
Woody (46,47,85)

Yeasty (46,84,85,87-90)

Additional Terms (introduced by panel).

Dull (85-87)
Sweet grain
Full-bodied (85)
Candyfloss-burnt sugar (51,85)
Perfumed scented(51)
Fragrant (46,47,85)
Toffee (85)
Creamy (85,88)
Mouth-drying (80)
Hay
Musty (46,47,51,85)
Watery (85,86)

Footnote to Table 1.

* Literature references indicate previous use of quality. Qualities which are underlined were included in the tertiary list of 75 qualities (see page 19).

specific applicability to (a) odour, (b) flavour-in-mouth and (c) aftertaste sensations. Following a second panel session using the same 6 assessors, a further 15 quality terms were eliminated. The remaining qualities were then classified into 45 groups based on previous publications,[46,47,84-86] private communications[87-90] and from the results of our panel of assessors. Thus an initial vocabulary was developed for use in the training programme (see Table 2 page 22).

In order to introduce certain of the less readily recognisable odour qualities of the vocabulary to the assessors, and by such exposure to widen their experience and their recognition of various odours, a library of 30 reference standards was constructed, (see Table 3, page 23). The majority of these have been recommended as standards by various workers and the supporting references are also quoted in Table 3. By presenting selected reference standards to the assessors, initially as labelled references and subsequently in blind tests during training, an association between odour quality terms as shown in Table 3 and perceived sensations was developed in the assessors' minds.

When the ability of assessors to recognise these odours had progressed, certain of the reference standards were then added to a canned beer at predetermined levels to present an odour complex in which the added quality was just noticeably recognisable. These levels were selected by a panel of 5 assessors. Examples of the levels used are seen in Table 4, page 25. Once the panel had become proficient at identifying these selected qualities, by comparing the odour of beers with and without the addition of reference standards, mixtures of standards from the library were then added to the canned

Table 2. Vocabulary used during training of assessors.

No.	Quality	
1	Estery, winey.	Qualities applied to odour, flavour-in-mouth and aftertaste
2	Fruity- citrus.	
3	Fruity- any other (please state).	
4	Floral, fragrant, cut grass.	
5	Herbal.	
6	Hop aroma.	
7	Perfumed, scented.	
8	Spicy.	
9	Diacetyl, buttery, creamy, butter oil.	
10	Sweet, sugary.	
11	Vanilla.	
12	Caramel toffee, burnt sugar, treacle, malt extract, honey.	
13	Burnt roasted.	
14	Burnt rubber.	
15	Grainy, granaries.	
16	Malty.	
17	Resinous woody.	
18	Sour grain.	
19	Yeasty, fermenting.	
20	Ammonia.	
21	Metallic.	
22	Phenolic, hospitals, antiseptic.	
23	Sulphur dioxide, pungent.	
24	Hydrogen sulphide, rotten eggs, putrid.	
25	Soapy.	
26	Etherish, solvents, anaesthetic, paint-like.	
27	Sour, acidic, sharp.	
28	Oxidised, stale, cardboard, straw-like.	
29	Overcooked cabbage, Dimethyl Sulphide (DMS).	
30	Onions, garlic.	
31	Fish oil.	
32	Oily, fatty.	
33	Bitterness immediate.	flavour-in-mouth only
34	Bitterness aftertaste.	aftertaste only
35	Salty.	flavour-in mouth-and aftertaste
36	CO_2 tingle.	
37	Clean no mouth coating.	
38	Thin, watery.	
39	Viscous.	
40	Warming.	
41	Dull.	
42	Full bodied.	
43	Mouth-drying.	
44	Mouth-coating.	
45	Gravity fullness	

Terms eliminated

Worty	Dry	Rubber
Sour-grain	Earthy	Hay
Smoky	Mealy	Musty
Sickly	Nutty	Hop oil
Cheese-like	Primings	Hop bitterness

Table 3. Details of the reference odours used during training of assessors.

Tube No.	Identification *	Odour Description	Preparation
1.	Amyl Acetate[88]	Pear Drops, Estery, Fruity (other)	5% in liquid paraffin
2.	Citral[88]	Lemon Oil, Citrus Fruits, Fruity Citrus	5% in liquid paraffin
3.	Ethyl Hexanoate[88]	Fruity, Estery, Wine Gums	5% in liquid paraffin
4.	Eugenol[46,47,88]	Cloves, Spicy, Pinks, Floral/Fragrant	5% in liquid paraffin
5.	Mixed Herbs	Herbal	Dried Herbs
6.	Hop Oil[88,89]	Hops	5% in liquid paraffin
7.	2-Phenyl Ethanol[47,88]	Roses, Floral, Fragrant, Perfumed, Scented	5% in liquid paraffin
8.	Mixed Spice	Spicy	Powdered Spice
9.	Diacetyl[88,89]	Buttery, Creamy, Butterscotch	0.15% in liquid paraffin
10.	Maltol[88]	Candyfloss, Sweet	Solid
11.	Vanillin[46,47,88]	Vanilla, Custard	Solid
12.	Caramel Essence[51]	Caramel, Toffee	Concentrated Essence
13.	Roasted Barley[88]	Roasted, Toasted, Sugar Puffs, Biscuits	Crushed roasted grain
14.	Burnt Rubber	Burnt Rubber	Shredded Burnt Rubber Tubing
15.	Malt Powder[88,89]	Malty, Horlicks	Malt Powder
16.	Cedar Wood Oil[88]	Resinous, Woody	Concentrated Oil
17.	Yeast	Yeasty	Fresh block yeast
18.	Phenol	Phenolic, Hospitals, Antiseptic	5% in liquid paraffin
19.	Sulphur Dioxide[51]	Pungent	Commercial Solution
20.	Sodium Sulphide[88]	H_2S, Rotten Eggs, Putrid.	1% aqueous solution
21.	Nonanol[88]	Soapy, Scented Soap	Concentrated
22.	Diethyl Ether	Etherish, Solvents	Concentrated
23.	Propionic Acid[88]	Sharp, Acidic, Sour	10% in liquid paraffin
24.	Stale Beer	Oxidised, Stale, Cardboard, Straw	Beer left open in sunlight
25.	Dimethyl Sulonide[46,47,88]	Overcooked Cabbage, Cabbage Water	0.01% in liquid paraffin
26.	Onion Powder	Onions	Dried onion powder
27.	Treacle[51]	Toffee Apples, Caramel, Burnt Sugar	Concentrated
28.	Perfume	Perfumed, Scented	Concentrated
29.	Malt Extract[88,89]	Treacle, Malty, Malt Extract	Concentrated
30.	Fermenting Yeast	Fermenting, Fresh Bread, Brewery Like	Bread yeast, flour and water

Footnote to Table 3.

* Literature references indicate previous recommendations of the use of each standard for description quoted. Although the same substance was used, preparation varied in some cases.

The descriptive terms underlined are those which appeared in the final analysis record form (Figure 1, page 26).

beer, again in the concentrations given in Table 4, p 25, and further blind odour tests were performed.

Training was then extended to include perception of both taste and odour sensations by adding compounds representing the four basic tastes and also other standards to the canned beer. Details can be seen in Table 5 page 25. On this occasion, the panel was asked to taste the beers and to describe the flavour-in-mouth sensations. When assessors could accurately identify these qualities in beer, the concept of aftertaste was introduced as an extension to the flavour-in-mouth experience and using the same reference standards. The sensation of aftertaste was assessed 2-10 seconds after the beer had been swallowed.

Finally, assessors were asked to describe the flavour qualities of 12 commercial beers in terms of odour, flavour-in-mouth and aftertaste, using the vocabulary shown in Table 2, page 22. These beers were selected to demonstrate the prominence of specific qualities (particularly burnt roasted, malty, hops, bitterness, sweetness and caramel toffee) naturally present in beers. During this stage, assessors were asked to group qualities according to the similarity of sensations perceived, and this produced a final vocabulary of 37 qualities agreed upon by the panel. Of these qualities, 24 were relevant to odour, flavour-in-mouth and aftertaste, 11 to flavour-in-mouth and aftertaste only, 1 was specific to flavour-in-mouth and 1 was specific to aftertaste. The final design of the profile form is seen in Figure 1, page 26.

Once the assessors had become familiar with this form by further qualitative assessments of numerous commercially available

Table 4. Concentrations of reference standards added to beer to demonstrate odour qualities.

Odour Quality	Reference standards used	Details of Preparation	No. cm^3 in $20cm^3$ beer
Fruity other, Estery	Amyl Acetate	$0.1cm^3 \rightarrow 100cm^3$ water	2
Fruity Citrus	Citral	$0.5cm^3$ (of 5% solution*) $\rightarrow 100cm^3$ H_2O	10
Herbal	Mixed Herbs (Dried)	5g + $100cm^3$ boiling H_2O, filtered	2
Spicy	Eugenol	$5cm^3$ (of 5% solution*) $\rightarrow 100cm^3$ H_2O	5
Hops	Hop Cone (Dried)	20g + $200cm^3$ boiling H_2O, filtered	5
Buttery etc.	Diacetyl	$1cm^3$ (of 0.15% solution*) $\rightarrow 100cm^3$ H_2O	10
Vanilla	Vanillin	$1g \rightarrow 100cm^3$ H_2O	10
Caramel	Commercial Essence	Used concentrated	2
Resinous woody	Ceder Wood Oil	$1cm^3 \rightarrow 100cm^3$ H_2O	1
Phenolic	Phenol	$1g \rightarrow 100cm^3$ H_2O	2
Pungent	Sulphur Dioxide	1% solution	2
Rotten, Putrid	Hydrogen sulphide	5g Na_2SO_4 + $100cm^3$ HCl $\rightarrow 100cm^3$ H_2O	1
Soapy	Nonanol	$0.5cm^3 \rightarrow 100cm^3$ H_2O	2
Etherish, Solvents	Diethyl Ether	$1cm^3 \rightarrow 100cm^3$ H_2O	2
Sour, Acidic, Sharp	Glacial Acetic Acid	$50cm^3 \rightarrow 100cm^3$ H_2O	2
DMS	Dimethyl sulphide	$0.5cm^3$ (of 0.01% solution*) $\rightarrow 100cm^3$ H_2O	3
Perfumed, scented	Commercial after-shave	$5cm^3 \rightarrow 100cm^3$ H_2O	5
		*Stock solution prepared in liquid paraffin	

Table 5. Concentrations of reference standards added to beer to demonstrate taste and odour qualities.

Taste Quality	Reference standards used	Details of Preparation	No. cm^3 in 20cc beer
Bitter	Caffeine	7g $\rightarrow$ 1L H_2O	2
Salt	Sodium chloride	20g $\rightarrow$ 1L H_2O	3
Sweet	Sucrose	100g $\rightarrow$ 1L H_2O	4
Sour	Citric Acid	7g $\rightarrow$ 1L H_2O	5
Fruity, citrus	Commercial Essence	$1cm^3 \rightarrow 100cm^3$ H_2O	1
Fruity, other	Commercial Essence	$10cm^3 \rightarrow 100cm^3$ H_2O	1
Caramel	Burnt sugar	$40g \rightarrow 100cm^3$ H_2O	4
Hops	Hops	$10g \rightarrow 500cm^3$ H_2O	4
Herbal	Mixed herbs	$5g \rightarrow 500cm^3$ H_2O	3
Spicy	Mixed spice	$5g \rightarrow 500cm^3$ H_2O	5
Malty	Malt extract	$50g \rightarrow 500cm^3$ H_2O	10
Vanilla	Vanilla Essence	$3cm^3 \rightarrow 100cm^3$ H_2O	1

Figure 1. Profile form used for assessment of selected beers

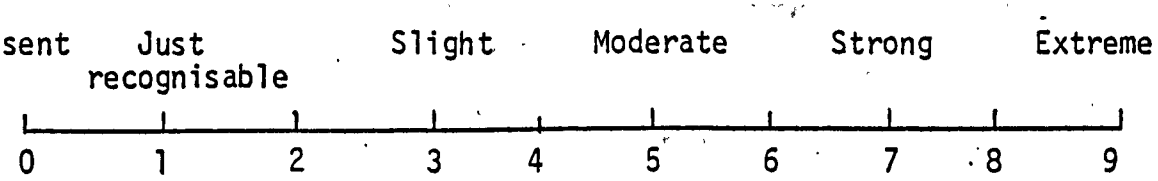
FLAVOUR PROFILE OF BEER

Assessors Name _____ Date _____ Sample Code _____

Quality	Odour	Flavour in mouth	Aftertaste
Fruity-other, Estery			
Fruity-citrus			
Floral, Fragrant, Perfumed, Scented			
Herbal			
Spicy			
Hops			
Caramel, Toffee, Vanilla, Buttery			
Burnt Roasted			
Grainy, Granaries			
Malty			
Resinous, Woody			
Yeasty (Fermenting)			
Metallic			
Burnt Rubber			
Phenolic, Hospitals, Antiseptic			
Pungent			
Rotten, Putrid			
Soapy			
Etherish, Solvents, Anaesthetic			
Oxidised, Stale, Cardboard			
Overcooked Cabbage, DMS			
Onions, Garlic			
Sour, Acidic, Sharp			
Sweet			
Bitterness-immediate			
Salty			
CO_2 Tingle			
Flat, Dull			
Viscous			
Smooth, Mellow, Full-bodied			
Thin, Watery, Lack of body			
Bitter-aftertaste			
Clean, No mouth coating			
Mouth coating			
Mouth drying			
Gravity Fullness			
Warming			

beers, quantitative analysis of the intensity of each flavour quality was then introduced. A linear 0-9, semi-structured category scale of intensity was used where 0 represented absence of a particular quality and 9 represented extreme intensity (see Figure 2).

Figure 2. Intensity Scale



To familiarise assessors with the scoring procedure, a wide range of 13 commercial canned and bottled beers were assessed over a number of sessions. These were chosen to demonstrate, as far as possible, varying intensities of many different flavour qualities found naturally in beer, in order to present the type of differences to be encountered during subsequent testing, and to encourage the panel to use the whole of the scale effectively.

Selection and use of reference beer.

Owing to inherent variations in the sensitivity of different individuals to various flavour qualities, some form of reference on the intensity scale relating to the profile form (Figure 1) was considered necessary. A commercial canned beer shown to possess a variety of flavour qualities at moderate intensities was chosen to provide this reference. Each assessor analysed the odour, flavour-in-mouth and aftertaste of this beer both qualitatively and quantitatively 4 times in the last stages of training, and a personal reference profile was thereby constructed based on each assessors own sensitivites. Assessors were then given their own personal reference

profile together with the reference beer in order to reassess (if necessary) and confirm the profile. Thereafter the final personal reference profile and a sample of the reference beer were always presented to the assessors whenever a beer was being analysed, thus providing both qualitative and quantitative intercomparisons of beers and reference points on the scale for a number of qualities.

A bulk supply of the reference beer was purchased to minimise risk of batch variation. After consultation with the Brewers, it was considered that its flavour would not be expected to show significant change during the analysis period of the selected beers, provided that storage conditions were adequate, i.e. at a beer temperature of 10^{o} - 13^{o}C without sudden fluctuation.

Selection and presentation of selected beers.

Beers selected for analysis were all commercially available in the London area and were purchased in the smallest quantity available in bulk containers, usually 9 gall. (40.9 l; a ferkin). Breweries supplying both beer types (i.e. BC and CC beers) were selected, ensuring that national companies marketing mainly BC beers, and local breweries, marketing mainly CC beers, were represented. All beers were collected from Breweries at the beginning of the week in which they were to be analysed and were stored and presented to assessors according to the recommendations of the Brewers, as follows. CC beers were tapped and spiled on arrival and settled for at least 48 h before analysis. All CC beers were clear and bright at the time of analysis and the nature of the head and the degree of gassiness indicated that fermentation was proceeding satisfactorily. The BC beers were not connected to gas cylinders until the morning of analysis

at which time carbon dioxide was applied according to the Brewers' recommendations. Every effort was made to maintain the hygiene standards of the containers and fittings. During the analysis period, the reference beer was stored under the same conditions as the selected beers in order to minimise temperature differences between samples. The average beer temperature during analysis was 12.5°C with a maximum of ± 1°C variation throughout the test period. Owing to time restrictions and the dynamic nature of CC beers, each selected beer was assessed once only.

Analysis of selected beers.

11 BC beers and 8 CC beers were analysed by the trained panel. All beers were coded with 3 digit codes and presented to assessors in dark red glasses, each containing approximately 50 cm^3 of beer. These glasses were chosen to mask any colour differences between beers and their height also disguised any variations in head characteristics. Analysis was performed in individual booths under fluorescent lighting balanced for daylight. The testing area was under positive pressure to exclude extraneous odours, and verbal communication between assessors was prohibted.

Since it was observed during training that the olfactory receptors were less sensitive after the beer had been tasted, odour assessments always preceeded flavour-in-mouth and aftertaste assessments. It was also observed that gentle swirling of the glass tended to release volatiles contributing to the odour of the beer, thus aiding identification of certain odour qualities. This was therefore encouraged during odour assessment. However it also caused beers to lose CO_2, thereby lowering the perceived gassiness, and for this reason,

CO_2 tingle was always assessed separately on a fresh sample of beer.

At each session, the following procedure was adopted. Each assessor was presented with the reference beer together with his/her personal reference profile for that beer. They were asked to assess the odour, flavour-in-mouth and aftertaste of the reference beer, simply to aclimatise themselves to beer and the testing situation. The assessor was then presented with a fresh sample of the reference beer, a sample of the selected beer to be analysed, and a blank profile form (Figure 1, page 26). A flavour profile of the selected beer was then constructed by comparison with the reference beer and its profile. Only 2 selected beers were assessed during any one session and the average analysis time, per sample, was 20 minutes. During this time fresh samples of the reference and selected beers were constantly available. Of the 22 potential assessors, 11 trained assessors (6 male, 5 females) attended every session and therefore only the results of these assessors were used in analysis of the data.

Results and Discussion

Total panel scores for each of the flavour qualities assessed are shown in Table 6, page 31. These were used to construct a composite model of the flavour of the 19 bitter beers analysed (Figure 3, page 32). In this model, bitter beer can be described as a beverage with the following flavour qualities:

(a) high levels of fruity, floral fragrant, spicy, sweet, hops, malty, caramel toffee, burnt roasted and yeasty odours.

(b) a prominence of bitter taste and aftertaste, with lower levels of the other 3 basic tastes.

Table 6. Summary data from descriptive analysis of 19 bitter beers.

Quality No.	Odour Qualities	TOTAL PANEL SCORES FOR BEERS																				Total Quality Score	Standard
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S			
1	Fruity Citrus	26	11	14	13	11	14	20	11	24	15	23	6	6	8	8	21	33	21	40		325	21
4	Fruity Other	51	18	32	29	39	37	37	31	58	34	49	43	11	35	21	28	49	24	38		674	33
7	Floral fragrant	6	5	11	5	8	6	9	22	10	6	10	15	7	8	0	18	21	30	33		230	9
10	Herbal	3	5	0	5	2	4	2	3	0	13	3	7	15	6	2	0	0	11	2		83	2
13	Spicy	15	25	11	8	4	4	15	4	15	16	11	10	2	6	5	15	10	5	9		191	4
16	Hops	17	18	16	13	19	15	19	20	12	21	12	36	30	28	28	20	15	60	19		418	19
19	Malty	17	13	14	7	25	14	12	26	14	7	5	7	0	13	13	6	20	0	11		225	12
22	Caramel Toffee	30	12	38	17	36	36	27	31	20	21	24	16	8	13	11	26	15	6	21		408	39
25	Burnt Roasted	7	40	13	20	6	11	17	9	15	4	15	12	10	16	15	19	11	3	3		246	2
28	Grainy	1	15	12	7	5	0	5	2	13	2	2	10	7	9	3	8	0	3	2		106	0
31	Yeasty	8	14	7	5	13	6	14	9	11	9	8	19	27	17	22	14	11	9	11		234	10
34	D.M.S.	7	16	13	16	6	6	9	5	5	8	3	8	25	8	17	6	4	8	8		179	13
37	Onions Garlic	0	2	0	0	0	0	0	0	0	0	0	0	12	0	3	0	0	0	0		17	0
40	Rotten Putrid	0	0	0	8	0	0	0	0	4	3	0	3	27	8	5	3	4	1	0		66	0
43	Oxidised Stale	0	4	3	10	0	2	0	8	7	2	0	2	10	1	6	0	0	0	1		56	0
46	Burnt Rubber	0	6	0	0	0	0	0	0	4	2	0	1	27	1	20	4	0	0	0		65	0
49	Pungent	0	1	0	0	0	0	0	0	2	0	0	0	0	0	2	1	0	0	0		6	0
52	Soapy	5	0	0	0	0	0	0	0	1	5	8	4	0	0	0	0	4	2	2		31	2
55	Phenolic	0	0	0	0	0	2	0	0	4	0	0	0	0	1	5	4	0	1	2		19	0
58	Etherish Solvents	0	3	0	1	0	0	0	0	4	0	1	0	0	0	0	3	0	8	0		20	0
61	Resinous Woody	4	5	1	6	0	0	0	3	2	0	0	1	6	4	0	4	4	0	4		44	0
64	Metallic	0	0	0	5	2	2	0	0	0	0	0	0	2	0	6	0	0	0	0		17	3
69	Sweet	29	16	31	20	11	19	20	25	18	13	29	10	5	11	9	17	33	31	32		379	20
72	Sour Acidic Sharp	3	4	3	1	6	2	1	2	9	4	0	9	18	11	12	9	4	4	2		104	8

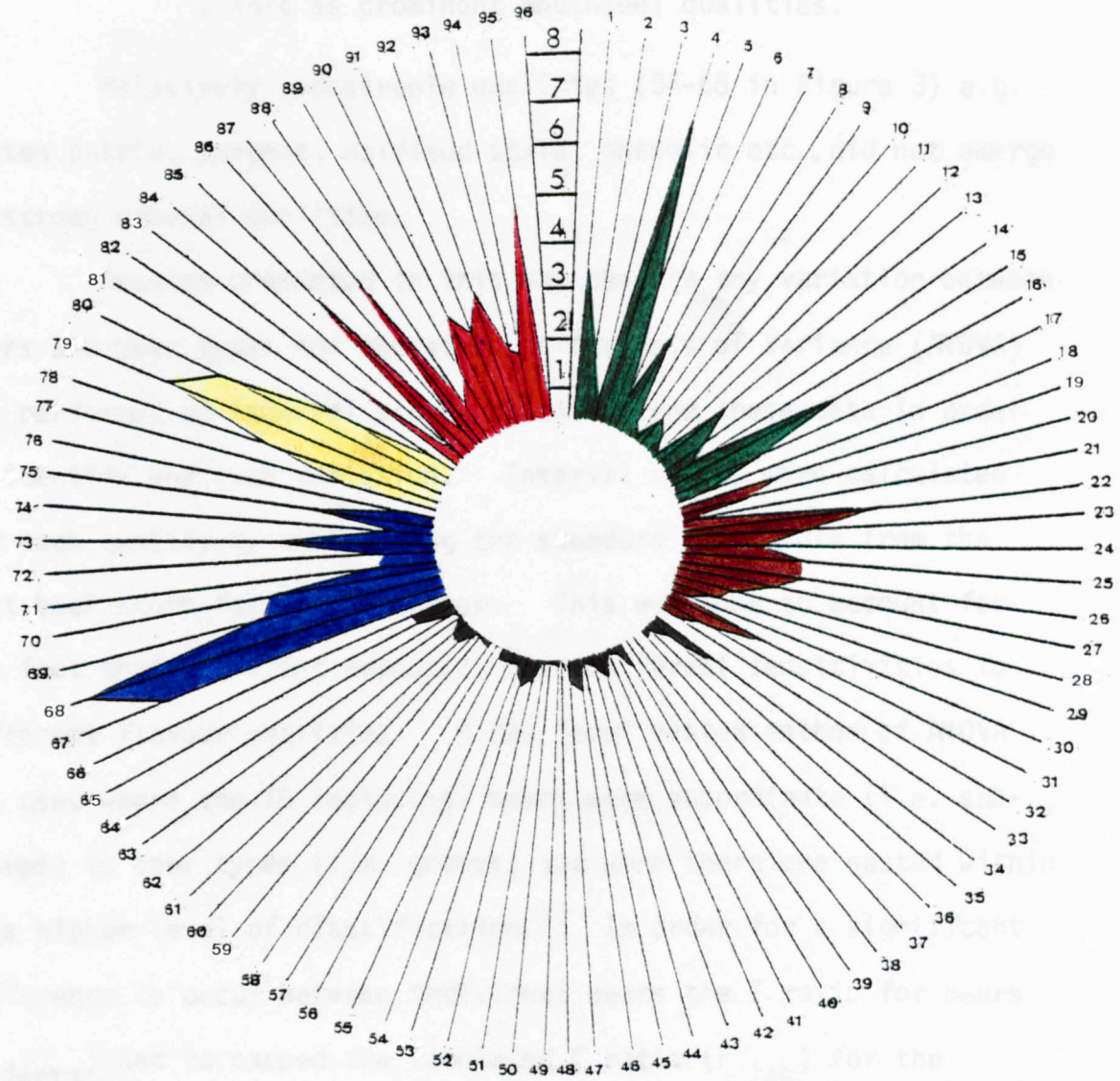
Quality No.	Flavour-in-Mouth Qualities	TOTAL PANEL SCORES FOR BEER																				Total Quality Score	Standard
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S			
2	Fruity Citrus	5	4	13	8	5	9	10	8	7	4	11	4	4	4	3	2	14	8	9		132	12
5	Fruity Other	18	9	13	16	18	17	16	13	25	12	15	26	10	13	14	22	16	11	7		391	5
8	Floral fragrant	0	0	0	1	4	0	2	1	0	0	0	0	0	6	5	0	9	5	11		44	0
11	Herbal	2	0	0	0	3	0	4	6	0	4	0	0	0	6	1	2	0	9	11		48	0
14	Spicy	5	14	4	3	4	3	3	3	9	5	14	5	5	7	2	6	9	1	4		106	0
17	Hops	4	5	4	9	7	2	16	8	10	16	6	16	14	13	10	10	2	30	8		190	7
20	Malty	8	5	14	6	15	8	12	19	10	0	7	2	3	10	5	4	12	0	3		143	4
23	Caramel Toffee	16	8	28	9	17	21	19	20	9	9	15	13	6	14	12	11	10	7	3		247	21
26	Burnt Roasted	11	23	1	14	17	4	17	8	13	2	11	12	21	19	20	21	10	12	9		245	0
29	Grainy	0	10	8	5	7	2	0	6	2	3	4	4	9	4	5	3	13	0	4		89	0
32	Yeasty	4	0	3	6	5	7	5	8	4	2	4	9	7	14	6	6	2	1	0		93	5
35	D.M.S.	2	5	1	5	0	3	2	2	1	6	0	1	13	0	0	0	0	3	0		44	0
38	Onions Garlic *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Not Scored		0
41	Rotten Putrid	0	0	2	0	0	0	0	0	0	0	0	1	3	0	0	2	0	0	0		8	0
44	Oxidised Stale	0	2	0	4	0	2	0	0	2	0	2	1	2	0	3	1	2	0	0		21	0
47	Burnt Rubber	0	3	0	1	0	0	2	0	7	2	0	0	10	0	13	4	0	0	0		42	0
50	Pungent *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0		1	0
53	Soapy	6	0	5	3	5	2	0	0	8	5	0	2	6	0	5	5	0	3	6		61	6
56	Phenolic	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	5	0	14	0		24	0
59	Etherish Solvents *	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	1	0		4	0
62	Resinous Woody	6	8	0	0	0	0	0	0	3	4	2	0	2	0	0	3	1	1	8		38	0
65	Metallic	5	6	0	8	0	3	3	4	8	8	2	0	0	4	17	10	3	0	0		81	15
67	Bitterness Immediate	32	30	20	31	35	23	19	31	38	42	12	42	36	40	37	37	29	33	54		620	21
70	Sweet	18	19	29	27	24	28	26	25	24	4	23	21	3	11	10	27	24	9	4		356	33
73	Sour Acidic Sharp	15	9	13	16	18	11	17	6	23	24	15	16	31	21	24	23	19	34	14		349	21
75	Salty	22	13	22	17	15	14	6	17	14	15	12	16	16	13	15	18	12	23	17		297	22
77	Warming	20	14	2	4	12	8	6	10	16	5	13	18	15	12	13	22	8	8	11		217	3
79	Gravity Fullness	34	37	22	25	34	27	31	35	44	33	38	42	35	37	28	39	35	32	27		635	21
81	Flat Dull	34	25	16	19	7	3	4	2	7	29	14	14	7	7	14	8	16	14	17		257	39
83	Viscous	12	19	5	6	12	8	15	13	24	7	26	25	20	14	12	20	19	13	8		278	2
85	Smooth Mellow	10	22	15	16	23	27	27	36	32	13	40	33	23	29	18	32	16	17	18		457	4
87	Thin watery	37	28	36	39	25	18	13	10	11	32	12	15	19	11	23	10	25	24	32		420	50
89	Clean	9	11	10	18	3	5	18	8	15	0	9	6	3	0	9	4	6	13	8		155	18
91	Mouthdrying	10	10	16	10	14	5	7	16	12	7	7	13	20	15	21	18	10	11	14		236	7
93	Mouthcoating	7	12	3	3	5	5	3	8	11	11	8	17	16	8	15	11	4	7	14		168	2
95	CO_2 Tingle	25	33	39	25	32	31	38	29	20	25	32	17	17	20	12	16	14	18	22		465	63

Footnote to Table 6 Qualities marked * were not included in the factor analysis (see page 43).

Quality No.	Aftertaste Qualities	TOTAL PANEL SCORES FOR BEERS																				Total Quality Score	Standard
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S			
3	Fruity Citrus	0	0	0	1	0	3	4	0	1	0	2	1	0	6	1	0	2	0	2		23	2
6	Fruity Other	4	5	2	1	6	4	6	4	10	4	4	3	1	7	2	4	7	3	3		80	4
9	Floral fragrant	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	5	4	4	20	0
12	Herbal	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	2	6		12	0
15	Spicy	7	3	1	0	0	1	4	6	5	4	3	3	0	4	1	7	2	0	0		51	1
18	Hops	0	0	0	0	0	3	0	0	5	0	5	8	5	0	0	0	12	0			38	0
21	Malty	0	2	2	0	5	0	0	2	0	0	0	0	0	0	0	2	0	0			13	0
24	Caramel Toffee	10	5	15	7	15	13	10	6	3	8	7	13	5	10	5	1	5	4	3		145	7
27	Burnt Roasted	9	17	10	8	9	6	10	11	4	10	2	12	23	11	15	13	14	6	7		197	2
30	Grainy *	0	5	0	0	5	0	0	3	0	5	0	0	0	0	0	0	3	0	0		21	0
33	Yeasty	0	0	0	3	2	4	2	4	1	0	1	5	0	2	1	1	0	0	0		26	1
36	D.M.S. *	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0		3	0
39	Onions Garlic *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Not Scored		0
42	Rotten Putrid *	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0		2	0
45	Oxidised Stale *	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0		2	0
48	Burnt Rubber	0	2	0	0	0	1	0	0	0	0	0	11	0	2	0	0	0	0	0		16	0
51	Pungent *	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0		1	0
54	Soapy *	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	4	0	0	0		9	0
57	Phenolic *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Not Scored		0
60	Etherish Solvents *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
63	Resinous Woody *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3		3	0
66	Metallic	5	5	0	5	5	2	0	5	4	7	7	10	2	2	9	4	6	0	5		83	10
68	Bitterness Aftertaste	32	31	24	41	37	29	25	42	46	54	24	53	54	52	52	53	38	47	54		788	24
71	Sweet	3	2	10	14	10	12	13	4	8	0	6	2	3	2	2	10	7	1	2		111	9
74	Sour Acidic Sharp	4	7	9	8	6	2	3	2	3	3	3	9	1	4	5	8	6	9	3		95	5
76	Salty	8	6	3	4	2	3	5	1	2	1	1	1	5	5	1	5	4	9	3		69	13
78	Warming	13	21	12	15	24	18	16	17	25	18	18	24	20	22	22	22	23	22	20		372	8
80	Gravity fullness	30	29	25	27	25	31	28	29	35	26	31	31	29	29	27	35	27	32	21		547	17
82	Flat Dull	0	7	0	4	0	0	0	0	4	0	0	6	3	0	8	5	5	0	7		49	14
84	Viscous *	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0		4	0
86	Smooth Mellow	0	0	0	0	0	0	0	5	4	0	3	4	0	0	8	5	0	5	0		34	0
88	Thin watery	0	13	9	2	6	5	8	2	5	0	2	6	5	0	4	6	5	6	7		91	16
90	Clean	12	25	33	20	17	24	14	23	8	5	28	14	14	14	6	7	15	4	5		288	30
92	Mouthdrying	9	12	13	18	13	12	9	19	14	19	12	15	14	20	21	22	12	21	25		300	11
94	Mouthcoating	6	5	3	2	2	2	3	3	9	17	5	7	9	5	14	10	14	17	11		144	2
96	CO_2 Tingle *	2	2	4	2	3	2	2	2	1	5	4	1	1	1	2	1	1	1	1		38	7

Footnote to Table 6 Qualities marked * were not included in the factor analysis (see page 43).

Figure 3. Composite model of the flavour of 19 bitter beers



Footnote: to Figure 3.

Radiating lines represent the intensity of each of the 96 qualities in terms of average panel scores. The colours represent an intuitive attempt at grouping flavour qualities according to apparent similarity and are intended only to clarify the diagrammatic representation.

The number on each radiating line corresponds to those shown in Table 6 p 31.

(c) a noticeable gravity fullness.

(d) smooth, clean, mouth-drying and CO_2 tingle as prominent mouthfeel qualities.

Relatively undesirable qualities (34-66 in Figure 3) e.g. rotten putrid, pungent, oxidised stale, phenolic etc., did not emerge as strong general qualities.

Results presented in this way obscure any variation between beers and beer types and therefore an Analysis of Variance (ANOVA) was performed on interval scores obtained from these data in order to identify any such variation. Interval scores were calculated for each quality by subtracting the standard beer score from the test beer score for each assessor. This was done to account for the fact that different assessors have different sensitivities to different flavour qualities. A two level nested method of ANOVA was used where the 19 individual beers were subordinate (i.e. sub-groups) to beer types (i.e. groups) and were therefore nested within this higher level of classification.[91] In order for a significant difference to occur between individual beers the F ratio for beers (F_{Beers}) had to exceed the tabulated F ratio (F_{Tab}) for the appropriate degrees of freedom. F_{Beers} may be defined as:-

$$\frac{MS_{Beers}}{MS_{Error}} = F_{Beers}$$

Where MS_{Beers} = Mean Square (or Variance) between (Subgroups / Individual beers) within (groups / beer types)

and MS_{Error} = Mean Square of the error, including assessor variation.

When F_{Beers} exceeded F_{Tab} the F-ratio for beer types was calculated as:-

$$\frac{MS_{Types}}{MS_{Beers}} = F_{Types}$$

Where MS_{Types} = Mean Square between (groups / beer types)

When F_{Beers} did not exceed F_{Tab} and the difference between beers (within subgroups) was not significant, F_{Types} was calculated as:-

$$\frac{MS_{Types}}{MS_{Error}} = F_{Types}$$

The F_{Types} values were compared with the F_{Tab} at the appropriate degrees of freedom in order to determine if the beer types differed significantly. In this way it was possible to establish whether significant differences existed (a) between the 19 individual beers and (b) between beer types i.e. the 8 CC beers and 11 BC beers. The BMDP programme P2V was used for this analysis.[92] When a difference was found between individual beers, a least significant difference (LSD) test was performed on the sample means in order to determine the nature of this difference.[93]

Results showed that the 19 individual beers differed significantly ($p \leq 0.05$) in terms of only 14 qualities. This does not necessarily mean that the remaining 72 qualities assessed were not important as beer flavour descriptors but simply that they were present at approximately the same intensities in all 19 beers analysed.

Results of the LSD test are shown in Table 7, page 36 . Most of the variation was due to odour qualities; this is not surprising when one appreciates the well established greater importance of odour over taste in the overall flavour complex (see page 11). Four of these odour qualities (burnt roasted, sweet, hops and fruity other) were exhibited by all 19 beers, 2 (floral fragrant and malty) were present in all beers except a small number of CC beers (beers O, M and R) and the remaining 3 odour qualities (onions garlic, rotten putrid and burnt rubber) were perceived at low intensities and mainly in CC beers. Bitterness immediate and bitterness aftertaste were possessed by all beers whilst hops, burnt rubber and resinous woody aftertastes were exhibited only by a minority of beers. Beer S was the only beer to exhibit a resinous woody aftertaste and since only two assessors scored this quality with a total score of 3, this result is not considered to be of major importance. Beer S also had the highest levels of bitterness immediate and bitterness aftertaste and it is proposed that the minority perception of resinous woody aftertaste could be related to high levels of these bitterness qualities.

These results indicated that certain qualities which differentiated significantly between the 19 beers were more universal among the beers than other qualities e.g. burnt roasted, sweet, hops, fruity other, floral fragrant and malty odours, also bitter taste and aftertaste. These therefore represent the most important distinguishing features of the flavour of bitter beers. Furthermore, those qualities not exhibited by all beers were perceived at lower intensity and were found most frequently in CC beers e.g. onions

Table 7. Location of significant differences ($p \leq 0.05$) between individual beers

BC Beers = A B C D E F G H I J K
CC Beers = L M N O P Q R S

Beers	B	D	P	G	N	I	K	O	C	L	F	Q	M	H	A	E	J	R	S
Burnt Roasted Odour																			
Score *	38	18	17	15	14	13	13	13	11	10	9	8	8	7	5	4	2	1	1

Beers	M	O	B
Onions Garlic Odour			
Score	12	3	2

Beers	M	D	N	O	I	Q	J	L	P	R
Rotten Putrid Odour										
Score	27	8	8	5	4	4	3	3	3	1

Beers	M	O	B	I	P	J	L	N
Burnt Rubber Odour								
Score	27	20	5	4	4	2	1	1

Beers	S	R	H	Q	P	L	C	I	K	G	N	E	M	A	F	J	B	D	O
Floral Fragrant Odour																			
Score	+25	+22	+14	+13	+10	+7	+3	+2	+2	+1	0	0	-1	-2	-2	-2	-3	-3	-8

Beers	Q	S	C	R	A	K	H	D	G	F	I	P	B	J	E	N	L	O	M
Sweet Odour																			
Score	+13	+12	+11	+11	+9	+9	+5	0	0	-1	-2	-3	-4	-7	-9	-9	-10	-11	-15

Beers	R	L	M	N	O	J	H	P	E	G	S	B	A	C	F	Q	D	I	K
Hops Odour																			
Score	+41	+17	+11	+9	+9	+2	+1	+1	0	0	0	-1	-2	-3	-4	-4	-6	-7	-7

Beers	I	A	K	Q	L	E	P	S	F	G	N	J	C	H	D	R	O	B	M
Fruity Other Odour																			
Score	+25	+18	+16	+16	+10	+6	+5	+5	+4	+4	+2	+1	-1	-2	-4	-9	-12	-15	-22

Beers	E	H	Q	A	C	F	I	B	N	O	G	S	D	J	L	P	K	M	R
Malty Odour																			
Score	+14	+14	+8	+5	+2	+2	+2	+1	+1	+1	0	-1	-3	-5	-5	-6	-7	-12	-12

Beers	S	J	L	N	I	O	P	M	E	R	A	D	H	B	Q	F	C	G	K
Bitterness Immediate †Fim																			
Score	+33	+21	+21	+19	+17	+16	+16	+15	+14	+12	+11	+10	+10	+9	+7	+2	-1	-2	-9

Beers	M	B	O	G
Burnt Rubber †At				
Score	11	2	2	1

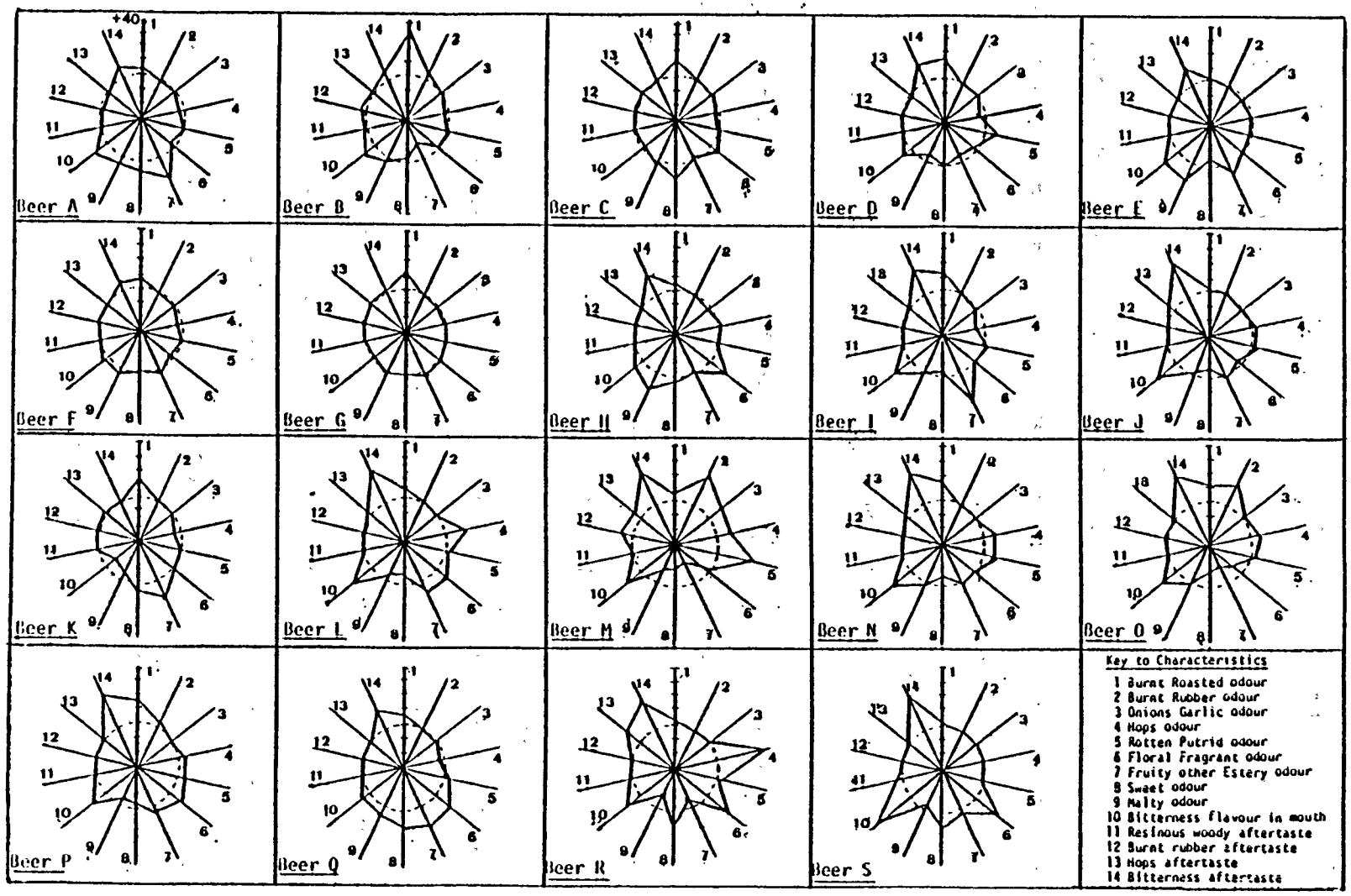
Beers	R	M	J	L	N	G
Hops At						
Score	12	8	5	5	5	3

Beers	S
Resinous Woody At	
Score	3

Beers	S	M	J	P	L	N	O	R	I	H	D	Q	E	A	B	F	G	C	K
Bitterness Aftertaste																			
Score	30	30	30	29	29	28	28	23	22	18	17	14	13	8	7	5	1	0	0

Footnote to Table 7. Beers underscored by the same line show no significant difference ($p \leq 0.05$) with respe to each particular flavour quality. Beers not underscored by the same line were found to differ significantly ($p \leq 0.05$) with respect to each particular flavour quality.
* Score = Panel interval scores; † At = Aftertaste, fim = flavour-in-mouth

Figure 4. Diagramatic representation of characteristics in which individual beers differed significantly ($p \leq 0.05$).



Footnote to Figure 4.

Each radius represents one flavour quality in which the beers differed significantly ($p \leq 0.05$); the distance of the intersect of the radii from the point of origin being equivalent to the total panel interval score for that quality in that beer. The scale on the radii extends from -30 at the origin to +40 at the extreme end. Positive interval scores represent qualities found at greater intensities in the experimental beers, whereas negative interval scores represent those found at greater intensities in the reference standard beer. The circle is drawn at zero level (i.e. the intensity of each quality in the reference standard beer).

garlic, rotten putrid, burnt rubber odours and hops aftertaste. This possession of a greater number of significantly different qualities indicates that the flavour of the CC beers was more varied than that of BC beers and was also associated with certain specific and distinguishing flavour qualities. Figure 4, page 37 illustrates this differentiation between CC beers (Beers L-S) and BC beers (Beers A-K). The circle at the zero level (equal to the intensity of that quality in the standard beer) emphasises the more irregular, diagramatic flavour profile of the CC beers with respect to the 14 qualities listed in Table 7. This applies especially to beers L, M, R and S. Despite this general trend, Figure 4 also shows that certain BC beers did show some prominent qualities. For example beer B differed significantly from all other beers in burnt roasted odour, beer I showed the highest fruity other odour and beer J had high bitterness immediate and aftertaste qualities. In general, Figure 4 shows that CC beers exhibited more prominent bitterness immediate and bitterness aftertaste qualities than did BC beers. Further specific variations are as follows: Of the CC beers (see also Table 7, page 36) beer M showed the highest level of variation by being significantly different from all beers tested in onions garlic odour, rotten putrid odour and burnt rubber aftertaste. Beer R was characterised by its prominent hops odour and aftertaste and its relatively high levels of sweet and floral fragrant odours. Beer L was also shown to have a prominent hops odour whilst beer S also had high levels of sweet and floral fragrant odours.

This prominence of certain flavour qualities in certain

beers suggested that it may be possible to typify beer types in terms of these qualities. The F ratio between groups (beer types) was found to be significant ($p \leq 0.05$) in the case of 22 flavour qualities shown in Table 8 below. Comparison of Table 7 p. 36 (significant differences between individual beers) and Table 8 (significant differences between beer types) show only four common qualities, i.e. hops odour, bitterness immediate, hops aftertaste and bitterness aftertaste. For the other 10 qualities in which the individual beers differed significantly, the variation between beers (within beer types) was greater than that between beer types. For the remaining 18 qualities in which the beer types differed significantly, but the individual beers did not, the variation between beers (within beer types) was smaller than the variation between beer types.

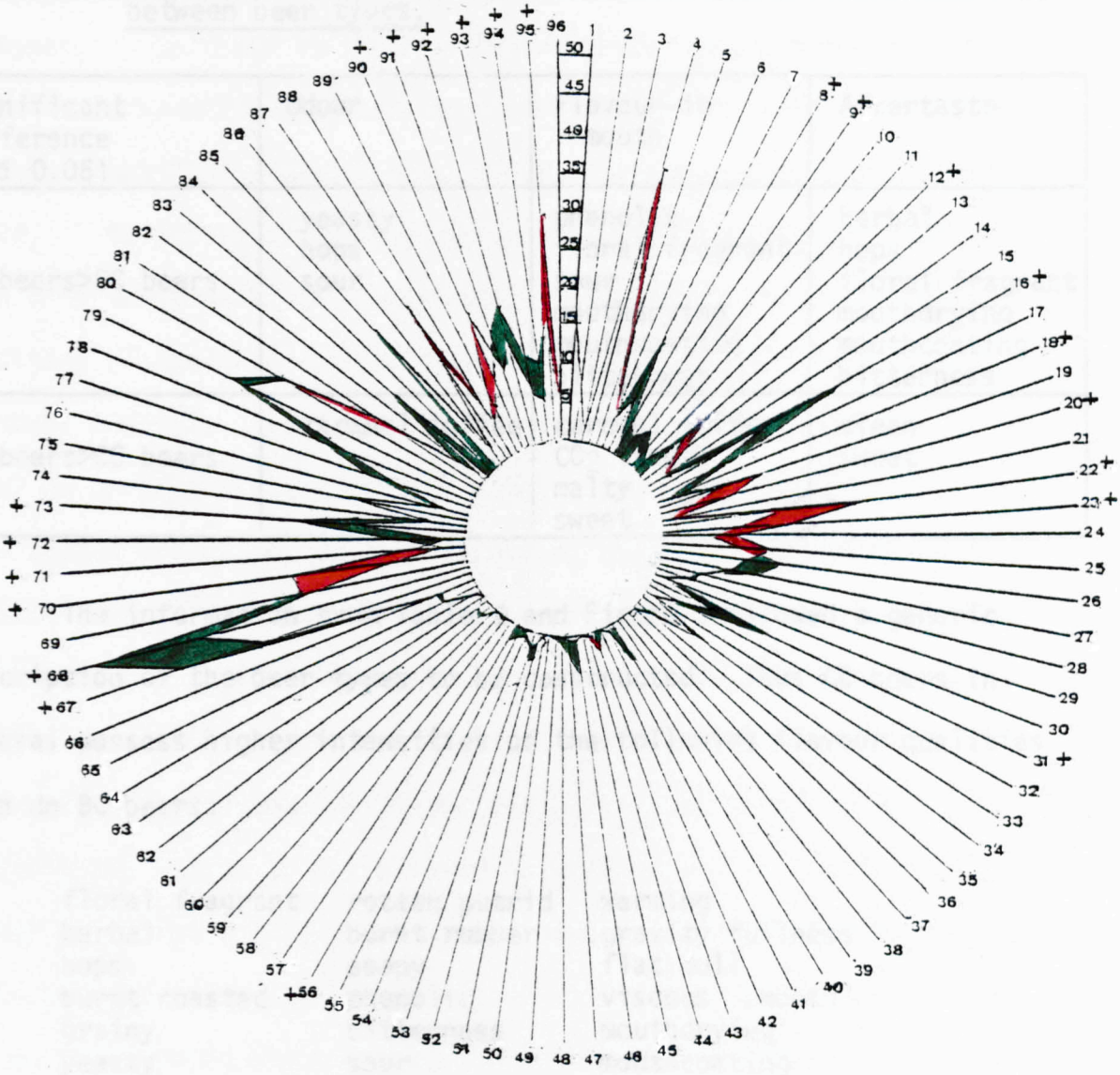
Table 8. Qualities showing significant difference between beer types ($p \leq 0.05$)

Flavour quality	flavour sensation	BC beers mean interval score	CC beers mean interval score	Difference	Beer type with highest mean
yeasty	odour	-0.55	+6.25	6.80	CCB
hops	odour	-2.45	+10.50	12.95	CCB
sour, acidic, sharp	odour	-4.82	+0.63	5.45	CCB
caramel, toffee	odour	-12.45	-24.50	12.05	BCB
sour, acidic, sharp	fm*[1]	-5.82	+1.75	7.57	CCB
caramel, toffee	fm	-5.45	-11.50	6.05	BCB
floral fragrant	fm	+0.73	+4.50	3.77	CCB
mouthdrying	fm	+3.36	+8.25	4.89	CCB
phenolic	fm	+0.18	+2.75	2.57	CCB
CO_2 tingle	fm	-33.10	-46.00	12.9	BCB
mouthcoating	fm	+4.91	+9.50	4.59	CCB
malty	fm	+5.45	+0.87	4.58	BCB
bitterness immediate	fm	+7.45	+17.38	9.93	CCB
sweet	fm	-10.55	-19.38	8.83	BCB
herbal	at*[2]	0	+1.50	1.50	CCB
mouthdrying	at	+2.64	+7.75	5.11	CCB
mouthcoating	at	+3.18	+8.87	5.69	CCB
clean	at	-11.00	-20.12	9.12	BCB
floral, fragrant	at	0	+2.50	2.50	CCB
hops	at	+0.73	+3.75	3.02	CCB
bitterness aftertaste	at	+11.0	+26.38	15.38	CCB
sweet	at	-1.55	-5.38	3.83	BCB

Footnote to Table 8 *1 fm = flavour-in-mouth
*2 at = aftertaste

Differences between beer types are presented diagramatically in Figure 5, page 40 and the significant differences ($p \leq 0.05$) are summarised in Table 9, page 41. In Figure 5, average panel

Figure 5. Highlighted differences between Beer Types



Footnote to Figure 5.

Radiating lines represent the intensity of each of the 96 qualities in terms of average panel scores. The differences between the two beer types are highlighted by the use of colours; red where BC beers > CC beers and green where CC beers > BC beers.

The number on each radiating line corresponds to those shown in Table 6 p 31.

+ represents qualities in which the two beer types differed significantly ($p \leq 0.05$).

Table 9. Flavour qualities showing significant difference ($p \leq 0.05$) between beer types.

Significant Difference ($p \leq 0.05$)	Odour	Flavour-in-mouth	Aftertaste
CC beers>BC beers	yeasty hops sour	phenolic floral fragrant sour mouthdrying mouthcoating bitterness	herbal hops floral fragrant mouthdrying mouthcoating bitterness
BC beers>CC beers	caramel toffee	caramel toffee CO_2 tingle malty sweet	clean sweet

The information from Table 9 and Figure 5 allowed a generic description of the beer types to be constructed. Thus CC beers in general possess higher intensities of the following flavour qualities than do BC beers:

floral fragrant	rotten putrid	warming
herbal	burnt rubber	gravity fullness
hops	soapy	flat dull
burnt roasted	phenolic	viscous smooth
grainy	bitterness	mouthdrying
yeasty	sour	mouthcoating

Conversely the qualities dominating BC beers are:

fruity other	caramel toffee	thin watery
spicy	oxidised stale	clean
malty	sweet	CO_2 tingle

The significant differences ($p \leq 0.05$) between CC beers and BC beers, as indicated by the ANOVA, are shown in Table 9 above.

Such a description of beer types does not take account of those qualities in which the 2 beer types did not differ significantly. Whilst the 22 qualities listed in Table 8 are the most important in distinguishing beer types, the relationship between all qualities

must be taken into account before these differences can be fully assessed. In order to examine the relationships between qualities, separate correlation matrices were constructed for each of the 3 flavour sensations assessed i.e. odour, flavour-in-mouth and after-taste. Whilst relationships between pairs of qualities could be seen from these matrices, the overall inter-relationships of all qualities within each flavour sensation could not be appreciated. A factor analysis was therefore performed on each matrix in order to arrange those qualities showing strong inter-relations into common groups, or factors according to the nature of their relationships.[94] The BMDP programme P4M was used for this analysis.[95] In this case principal component analysis is used to extract the factors from the correlation matrix. Varimax rotation is then used during the subsequent factor analysis. In this form of analysis the degree of correlation between qualities within one factor is called the factor loading; qualities with high loadings on a factor tend to be highly correlated with each other. Each factor may be interpreted according to the magnitudes of the loadings associated with it, and therefore those qualities with the highest loadings contribute more to the interpretation of that factor. In order to simplify this interpretation, a significance level is chosen such that any factor loading greater than that required for significance at this level is regarded as contributing more to the nature of that factor. For the purpose of this research, the level of ± 0.300 was chosen, because, although regarded as a rigorous level, it would allow the more important qualities to be more readily identified.[96] Those qualities with loadings greater than ± 0.300 are shown in

Tables 10-12 (p 44-46). In order to increase the efficiency of the factor analysis, certain qualities were excluded - such exclusion being based upon the frequency and consistency with which the qualities were used by the assessors. The qualities excluded are marked with an asterisk in Table 6, p 31. The number of factors extracted and the variance explained is shown in Tables 10-12, pages 44-46. Thus the odour qualities were arranged into 9 factors, flavour-in-mouth into 11 factors and aftertaste into 10 factors.

Tables 10-12 show that certain qualities have loadings which are significant in more than one factor and as such are related to different groups of qualities. For example in odour factor 1 , caramel toffee shares positive loadings with sweet and floral fragrant whereas in odour factor 4 , caramel toffee is positively related to malty and fruity other odours. It would appear that the odour qualities grouped in this manner in factors 1 and 4 explained two facets of the flavour complex of these beers, with caramel toffee playing an important part in each facet.

In order to discover how important these and other qualities were to individual beers and to beer types, it was necessry to investigate variations between individual beers and beer types in terms of the extracted factors. A value was computed that would represent each factor in each beer. This was the factor score. Factor scores (fi) were computed as part of the BMDP factor analysis programme P4M[95] and expressed as:

$$fi = bi_1 Z_1 + bi_2 Z_2 + \ldots\ldots + bip\ Zp$$

where bij are the factor score coefficients.

Zj is the jth standardised variable.

Table 10. Odour factor loadings ≥ ± 0.300 (x 10^3)

Factor	Quality	Loading
1 (variance explained 14.8%)	rotten, putrid	+771
	D.M.S.	+593
	yeasty	+544
	grainy	+477
	sweet	-623
	caramel, toffee	-360
	floral	-300
2 (variance explained 10.0%)	ether	+743
	phenolic	+698
	pungent	+556
	burnt rubber	+309
	caramel, toffee	-434
3 (variance explained 7.5%)	fruity citrus	+739
	sour	+707
	oxidised	-534
4 (variance explained 7.2%)	malty	+776
	caramel, toffee	+382
	fruity other	+355
	herbal	-695
	hops	-322
5 (variance explained 5.5%)	metallic	+850
	fruity other	-468
	floral	-415
6 (variance explained 5.2%)	onion	+847
	burnt rubber	+749
7 (variance explained 5.0%)	resinous	+761
	oxidised	+333
	hops	-427
	DMS	-370
8 (variance explained 4.5%)	soapy	+774
	spicy	-600
	yeasty	-376
	grainy	-321
9 (variance explained 4.3%)	burnt roasted	+817
	hops	+416
	fruity other	-375
	floral	-345

Footnote to Table 10 64% of the total variance was explained by these 9 factors.

Table 11 Flavour-in-mouth factor loadings ≥ ±0.300 (x 10^3)

Factor	Quality	Loading
1 (variance explained 12.6%)	viscous	+777
	gravity fullness	+761
	warming	+670
	burnt roasted	+481
	smooth	+455
	spicy	+339
	watery, thin	-800
	fruity citrus	-559
2 (variance explained 10.2%)	grainy	+724
	hops	+601
	spicy	+552
	malty	+539
	CO_2 tingle	+466
	soapy	-774
3 (variance explained 8.0%)	clean	+805
	caramel, toffee	+594
	sour	+374
	mouthcoating	-719
	metallic	-305
	smooth	-412
4 (variance explained 6.9%)	floral	+779
	herbal	+738
	caramel, toffee	-510
	sweet	-362
5 (variance explained 5.0%)	flat	+831
	metallic	+672
	fruity citrus	-503
	smooth	-328
6 (variance explained 4.9%)	salty	+860
	bitterness	+551
	sweet	-389
	CO_2 tingle	-372
7 (variance explained 4.5%)	fruity other	+781
	yeasty	+301
	sour	-655
	CO_2 tingle	-361
8 (variance explained 4.0%)	yeasty	+735
	resinous	-632
	burnt rubber	-418
9 (variance explained 3.7%)	phenolic	+841
	burnt rubber	+483
	burnt roasted	+397
	sweet	-310
10 (variance explained 3.5%)	oxidised	+771
	DMS	+589
	sweet	-384
11 (variance explained 3.2%)	rotten	+666
	mouthdrying	+622

Footnote to Table 11 66.5% of the total variance was explained by these eleven factors.

Table 12 Aftertaste factor loadings ≥ ±0.300 (x 10^3)

Factor	Quality	Loading
1 (variance explained 14.6%)	watery, thin	+876
	flat	+817
	sweet	+533
	metallic	+410
	caramel, toffee	-655
	bitterness	-401
2 (variance explained 9.3%)	salty	+744
	metallic	+714
	flat	+428
	burnt roasted	-704
3 (variance explained 8.2%)	gravity fullness	+859
	warming	+851
	metallic	+343
	salty	-434
4 (variance explained 7.4%)	mouthcoating	+760
	bitterness	+595
	clean	-671
	caramel, toffee	-375
5 (variance explained 6.4%)	herbal	+760
	floral	+681
	hops	+661
	sour	-323
6 (variance explained 5.8%)	mouthdrying	+726
	fruity citrus	+395
	spicy	-727
7 (variance explained 5.3%)	fruity other	+762
	fruity citrus	+708
8 (variance explained 4.6%)	malty	+740
	sour	-599
	yeasty	-310
9 (variance explained 4.3%)	burnt rubber	+787
	yeasty	-522
10 (variance explained 4.1%)	smooth	+847
	yeasty	-419

Footnote to Table 12 70.0% of the total variance was explained by these ten factors.

Correlation between qualities had already been accounted for by the factor analysis and therefore use of factor scores in analyses such as analysis of variance, and multiple regression, where correlation between variables is undesirable, is an advantage.

Since factor scores express the degree to which each beer possesses the overall quality described by that factor, it was possible to perform an ANOVA on the factor scores in order to determine the variation between beers and between beer types in terms of the extracted factors. The BMDP (P2V) programme[92] was used for this analysis.

Results showed that individual beers differed significantly in terms of 5 factors (Table 13, page 48) whilst beer types varied significantly in 9 factors (Table 14, page 49). As with previous analyses, odour qualities accounted for most of the variation. All odour qualities in which individual beers differed significantly (see page 36), appeared prominent in the significant factors with the exception of burnt roasted odour. The individual beers did not differ significantly in any flavour-in-mouth factors. Only one aftertaste quality, i.e. burnt rubber aftertaste, was significant in both the previous analysis (see page 36) and also prominent in this analysis of factor scores. Beer M was particularly highlighted; it was found to differ significantly from all other beers in 3 of the 5 factors, the qualities prominent in that variation being those with high positive loadings in odour factors 1 and 6 and aftertaste factor 9. i.e. rotten putrid, DMS, yeasty, grainy, onions, burnt rubber odours and burnt rubber aftertaste. Reference to the interval

Table 13 Location of significant differences ($p \leq 0.05$) between individual beers in terms of factors

Beers	M	N	O	L	D	I	B	E	J	P	H	R	Q	G	C	A	F	S	K
Odour Factor 1	—																		
Factor score	+1.5	+0.4	+0.4	+0.4	+0.1	+0.1	+0.1	0	0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.5	-0.5

+		−	
rotten	771	sweet	-623
D.M.S.	593	caramel	
yeast	544	toffee	-360
grainy	477	floral	-300

Beers	I	E	H	Q	A	C	F	O	P	G	B	N	K	S	D	L	J	M	R
Odour Factor 4	—																		
Factor score	+0.7	+0.6	+0.4	+0.4	+0.3	+0.3	+0.2	+0.2	+0.1	0	0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3	-0.6	-1.2

+		−	
malty	776	herbal	-695
fruity		hops	-322
other	355		
caramel			
toffee	382		

Beers	M	O	B	P	Q	K	G	S	I	J	A	N	F	C	E	H	L	D	R
Odour Factor 6	—																		
Factor score	+1.9	+0.7	+0.2	0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3

+		−	
onions	847		
burnt rubber	749		

Beers	J	R	O	S	P	Q	I	M	N	L	A	B	H	D	G	E	K	F	C
After-taste Factor 4	—																		
Factor score	+0.9	+0.5	+0.5	+0.5	+0.4	+0.3	+0.2	+0.2	+0.1	0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.5	-0.5	-0.7	-0.8

+		−	
mouth-coating	760	clean	-671
bitter-ness	595	caramel	
		toffee	-375

Beers	M	B	C	S	G	K	E	A	O	Q	R	D	I	P	F	J	N	H	L
After-taste Factor 9	—																		
Factor score	+1.4	-0.3	+0.2	+0.1	+0.1	+0.0	+0.0	+0.0	+0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.5	-0.4	-0.5

+		−	
burnt rubber	737	yeasty	-522

Footnote to Table 13. Beers underscored by the same line showed no significant difference ($p \leq 0.05$). Beers not underscored by the same line were found to differ significantly ($p \leq 0.05$). BC beers = red: CC beers = green.

Table 14 Details of factors in which beer types were found to be significantly different ($p \leq 0.05$)

Quality/ Factor	Panel Score BCB	Panel Score CCB	Type	Prominent Qualities and Factor Scores			
Odour Factor 1	-16.78	+19.21	CCB	Rotten + 771	DMS 593	Yeasty 544	Grainy 477
			BCB	Sweet - 623	Caramel 360	Floral 300	
Odour Factor 3	-19.37	+19.21	CCB	Fruity Cit.+739	Sour +707		
			BCB	Oxidised - 534			
Odour Factor 4			BCB	Malty +776	Fruity Oth.355	Caramel 382	
			CCB	Herbal -695	Hops 322		
Odour Factor 6	-17.69	+18.26	CCB	Onion +847	B.Rubber 749		
			BCB	--	--		
Flavour in-mouth Factor 4	-22.18	+22.51	CCB	Floral +779	Herbal 738	Hops 286	
			BCB	Caramel -510	Sweet 362		
Flavour in-mouth Factor 6	-18.26	+18.20	CCB	Salty +860	Bitter 551		
			BCB	CO_2 -372	Sweet 389		
Aftertaste Factor 4	-29.3	+29.44	CCB	M'coating +760	Bitter 595		
			BCB	Clean -671	Caramel 375		
Aftertaste Factor 5	-23.87	+24.46	CCB	Herbal +760	Floral 681	Hops 661	
			BCB	Sour -323			
Aftertaste Factor 6	-15.38	+15.43	CCB	M'drying +726	Fruity 395		
			BCB	Spicy -727			

scores for this beer confirmed this trend and revealed that, as expected, this beer had low scores for qualities with negative loadings in these factors. The high hops and herbal odours of Beer R were reflected in the position of this beer in odour factor 4, where it differed from all other beers except Beer M. Once again, Beer R had low original scores for those qualities negatively correlated with hops and herbal odours in this factor, i.e. malty, fruity other and caramel toffee. This bipolar nature of the factors has been represented in Figure 6, page 51 where the correlation between prominent qualities in each factor may be seen more clearly.

It was in the results of the ANOVA of beer types that this bipolar relationship became even more apparent, (Fig.7, p. 52), and it was possible to identify the orientation of each factor towards the beer types. For example, interval scores showed BC beers to have higher scores for malty, caramel toffee and fruity other odours, whereas CC beers had higher scores for hops and herbal odours. In odour factor 4, not only was the relationship between these qualities apparent but the factor could also be regarded as directional for the two beer types. Other factors showing this directional behaviour were odour factor 3, flavour-in-mouth factors 4 and 6 and aftertaste factors 4 and 6. The direction of these factors (i.e. whether associated with BC beers or CC beers) is shown in Table 14 page 49. Odour factor 6 showed only two qualities with significant loadings, i.e. onions garlic and burnt rubber. Since both qualities had higher scores for CC beers, this factor may be regarded as a direct indicator of this beer type. In aftertaste factor 5, all four qualities with

Figure 6 Bipolar models of factors in which individual beers were found to differ significantly ($p \leq 0.05$)

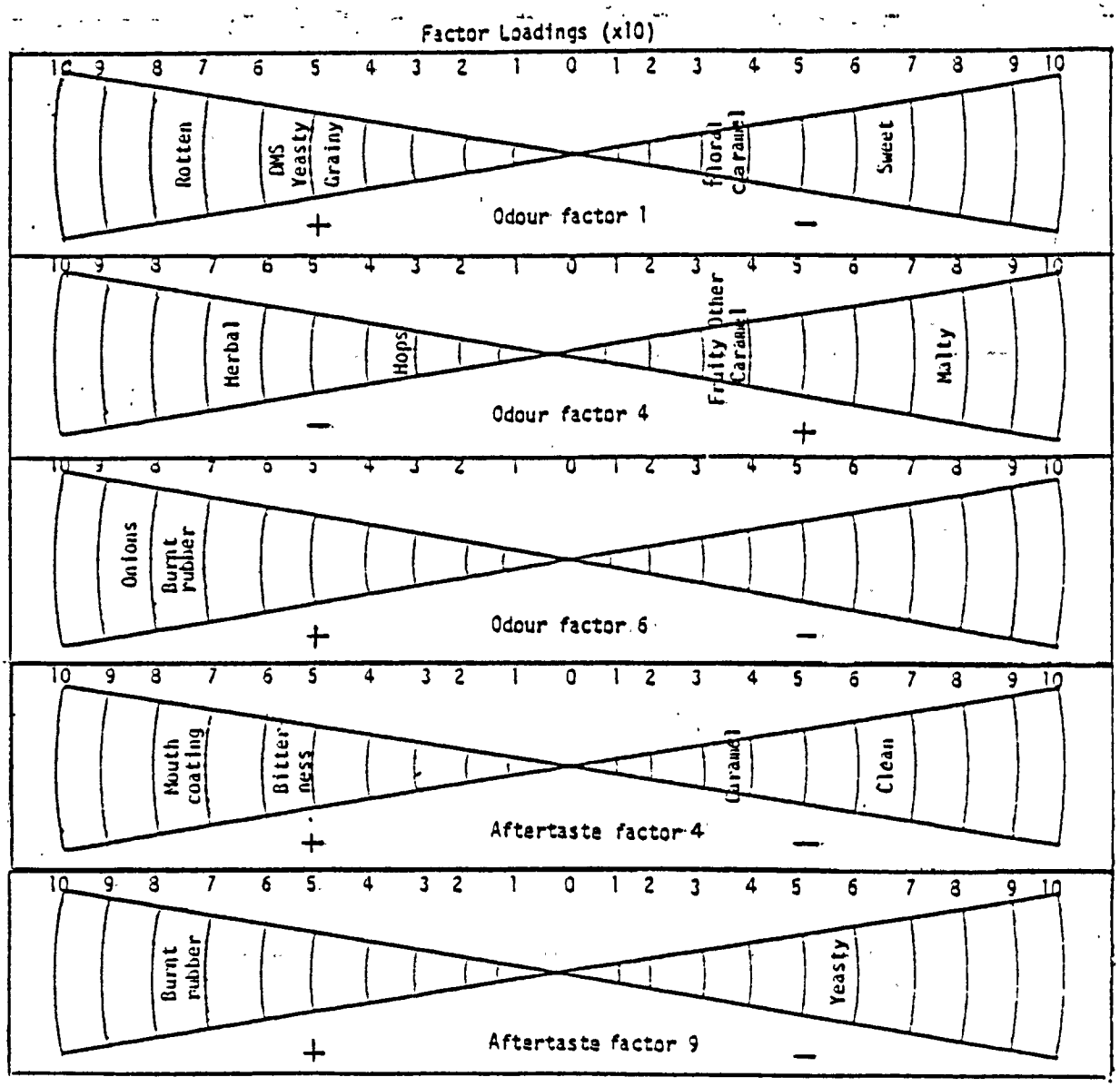
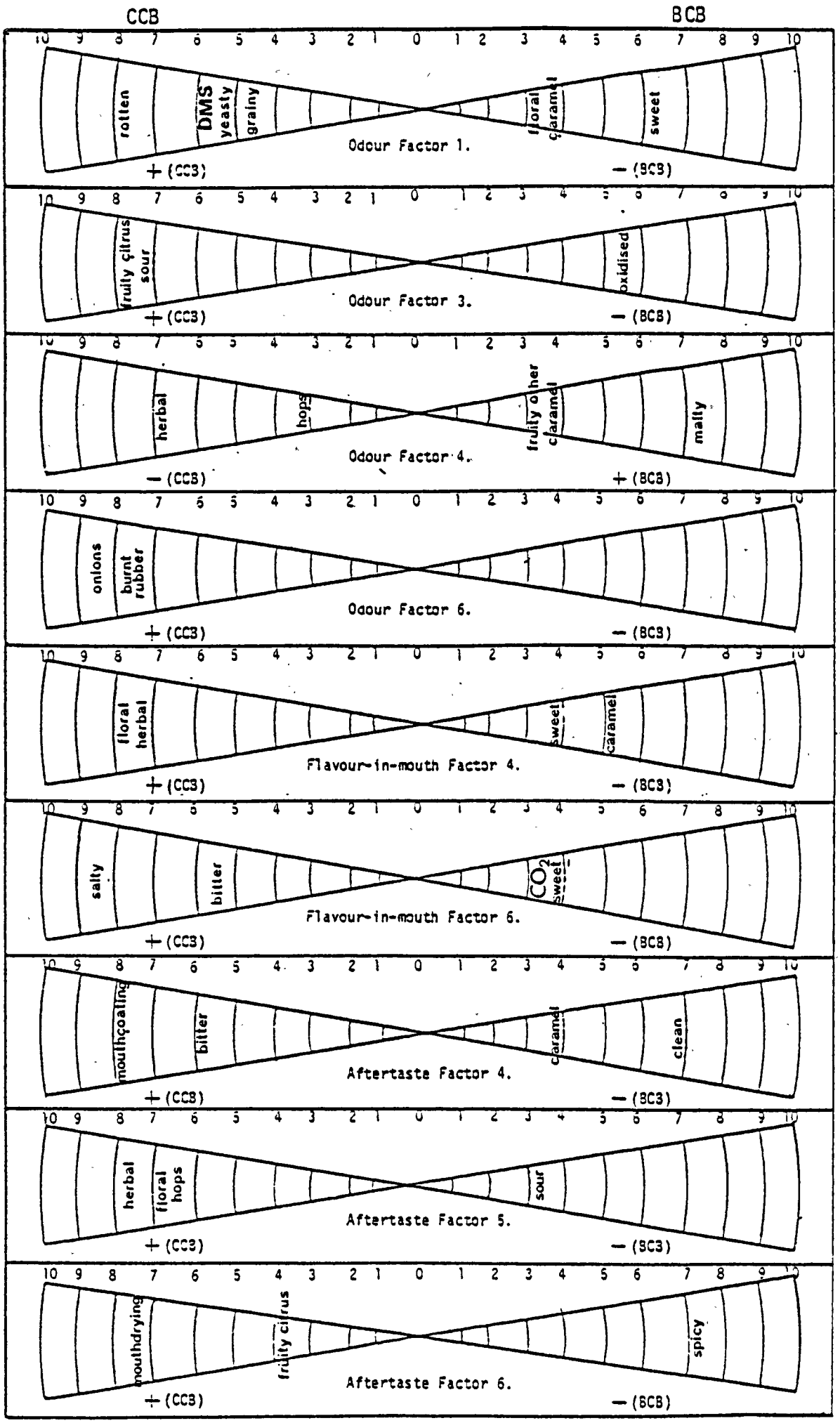


Figure 7 Bi-polar model of factors in which beer types were found to differ significantly ($p \leq 0.05$).

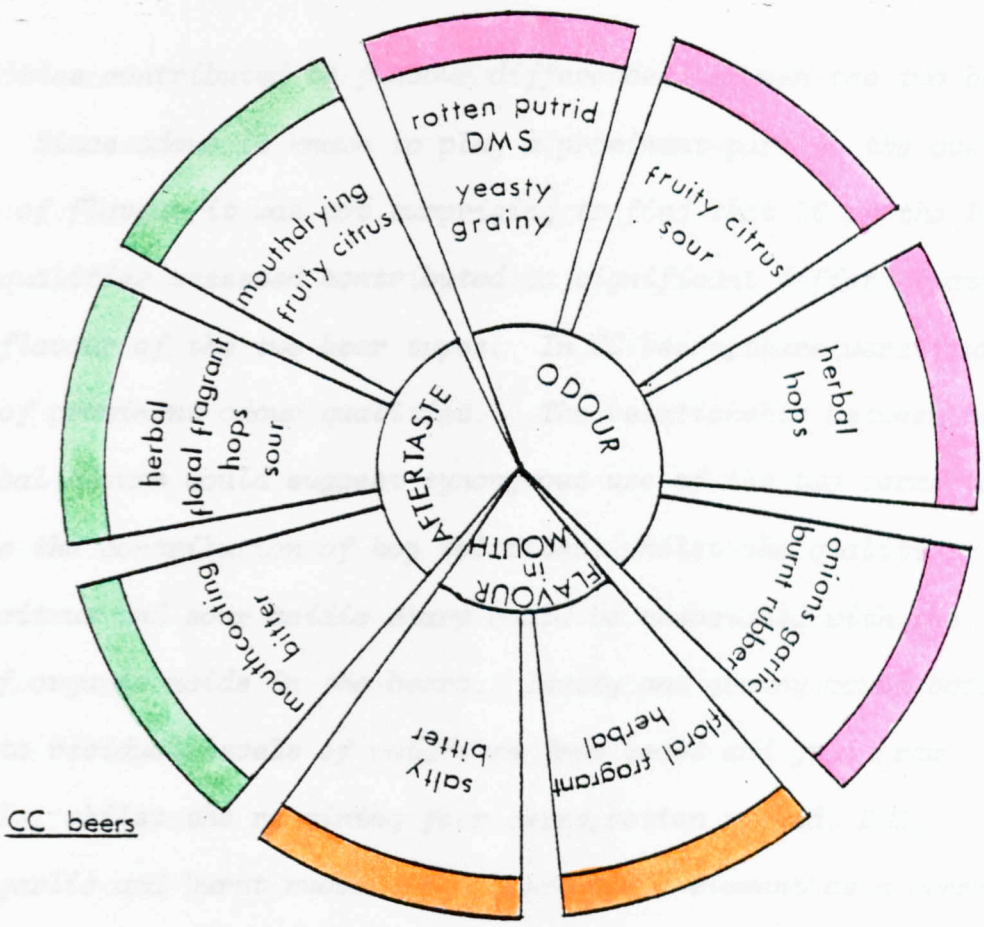


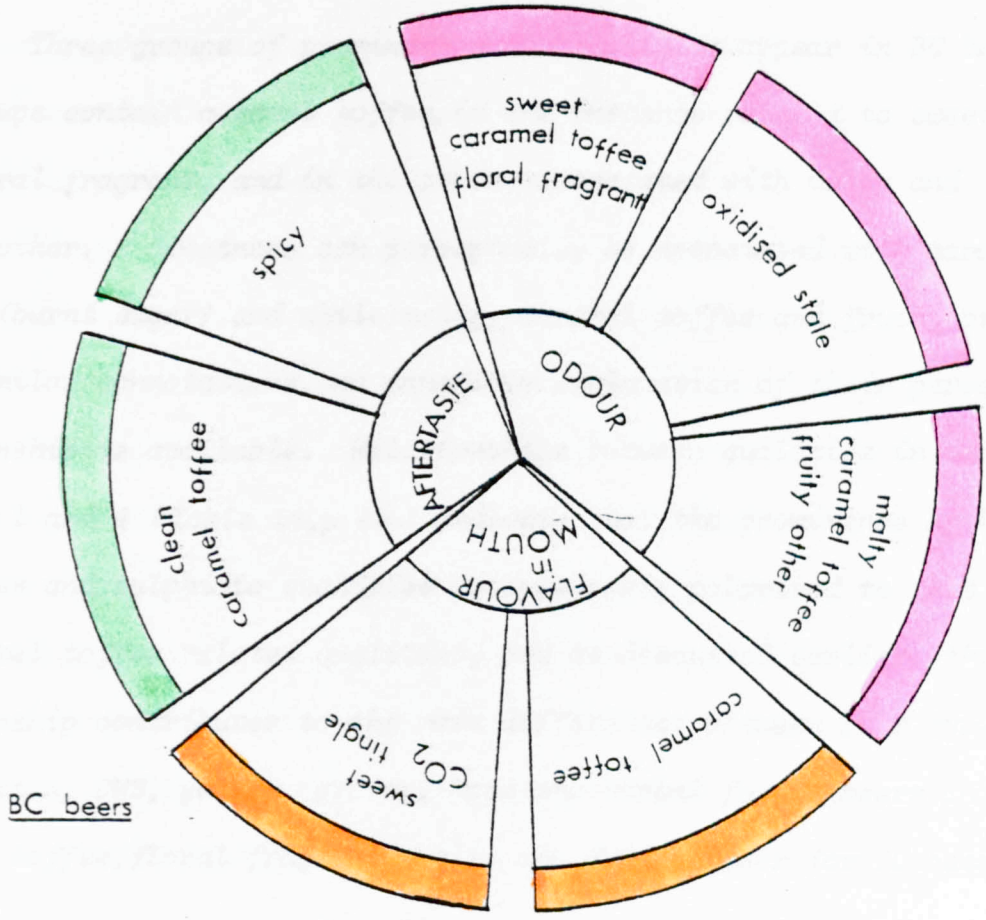
Footnote to Figure 7 BCB = BC beer; CCB = CC beer

significant loadings were scored higher for CC beers, although sour acidic sharp was shown to be negatively correlated with hops, herbal and floral fragrant in this factor. Interval scores showed that when CC beers were scored highly for hops, herbal or floral fragrant, they received a lower score for sour acidic sharp. This explains the relationship shown in this factor. The interval data also showed that most BC beers had been scored for sour acidic sharp, whereas none were scored for herbal or floral fragrant aftertastes and only two for hops aftertaste. Therefore, whilst CC beers had a higher overall score for sour acidic sharp, the perception of that quality in a beer would be less indicative of the beer type than the prominence of hops, herbal or floral fragrant aftertaste. The relationship between qualities in odour factor 1 was less well defined. Rotten putrid, DMS and yeasty odours received higher scores in CC beers and were positively correlated with grainy odours which received higher scores in BC beers. Similarly caramel toffee and sweet, both with higher scores in BC beers were positively correlated with floral fragrant, which had a higher score in CC beers. Both floral fragrant and grainy had the lowest significant loadings in that factor and reference to the interval scores for the other qualities do give this factor some overall direction with respect to beer types.

Information from the ANOVA on factor scores made it possible to present a generic description of the flavour of the two beer types in terms of groups of related qualities. These are presented diagrammatically in Figure 8 (page 54) which shows that 34 of the

Fig. 8 Flavour qualities prominent in the two beer types





Footnote to Fig. 8 Qualities are arranged according to their factor loadings as shown in Table 14; those qualities nearest the rim of the circle have the greatest factor loadings and therefore contribute more to the characterisation of the factor.

96 qualities contributed to flavour differences between the two beer types. Since odour is known to play a prominent part in the overall concept of flavour, it was not surprising to find that 16 of the 24 odour qualities assessed contributed to significant differentiation of the flavour of the two beer types. In CC beers, there were four groups of prominent odour qualities. The relationship between hops and herbal odours would suggest synonymous use of the two terms to describe the contribution of hop volatiles, whilst the qualities fruity citrus and sour acidic sharp could be associated with the level of organic acids in the beers. Yeasty and grainy could both relate to residual levels of volatiles from yeast and grain raw materials, whilst the remaining four terms, rotten putrid, DMS, onions garlic and burnt rubber have a sulphidic element as a common link; this will be discussed later.

Three groups of prominent odour qualities appear in BC beers. Two groups contain caramel toffee, in one instance related to sweet and floral fragrant, and in the other, associated with malty and fruity other. Sweetness can perceptually be associated with caramel toffee (burnt sugar) and while malty, caramel toffee and fruity other have similar connotations, no immediate explanation of their perceptual relationship is available. Relationships between qualities in odour factors 1 and 4 (Table 14, p 49) indicate that the prominence of hop volatiles and sulphidic qualities is oppositely polarised to that of caramel toffee related qualities, and as discussed earlier, this relationship contributes to the main differences between beer types i.e. rotten, DMS, yeasty, grainy, hops and herbal for CC beers and sweet, caramel toffee, floral fragrant, malty and fruity other for BC beers.

The third odour group in BC beers contains only one prominent quality i.e. oxidised stale, used in this research to describe odours associated with oxidative degradation of bitter beers.

Only 7 of the 33 flavour-in-mouth qualities were extracted as prominent contributors to flavour. However, it should be remembered that 24 of these 33 qualities were in effect odour qualities i.e. perceived by the olfactory receptors via the nasopharyngeal passage while the beer was in the mouth. Following observations during the analysis of beers by trained assessors, it is also proposed that a fatigue effect operated. It was shown that sensitivity to odour qualities detected directly by inhalation of volatile compounds into the nose, decreased once the beer had been taken into the mouth. Whilst no explanation of this phenomenon is readily available, it is clear that it caused a decrease in detection of odours present whilst the beer was held in the mouth. It was observed that the level of olfactory sensitivity increased after oral rinsing with water and a short rest period.

Discrimination between beer types in three of the four basic tastes (salt, bitter and sweet) and a mouthfeel quality (CO_2 tingle), suggests that the fatigue effect, earlier mentioned, was specific to the olfactory receptors. Three flavour in mouth qualities, caused by stimulation of the olfactory receptors while the beer was in the mouth, were perceived with sufficient acuity to allow discrimination between beer types and since these were also prominent as odour and aftertaste qualities, this suggests that they were persistent enough to overcome the possible olfactory fatigue effect. Of these three qualities, caramel toffee was found to be negatively correlated with

hops and its associated qualities (herbal, floral)-a relationship also shown amongst odour qualities (see factor 4, Table 10). Bitterness was shown to be positively related to salty and negatively related to two qualities prominent in BC beers i.e. sweetness and CO_2 tingle.

Persistence of volatile components would be particularly noticeable during assessment of aftertaste, when a combination of lingering volatiles and basic tastes together with residual mouthfeel qualities would be expected to contribute to the variation. Of the eleven qualities prominent in aftertaste differentiation between the 2 beer types, two represented the basic tastes, (bitter and sour), three were mouthfeel qualities (mouthcoating, mouthdrying, clean) and six were odour qualities. The relationship between mouthfeel qualities show mouthcoating to be negatively correlated with its antonym clean, no mouthcoating. The association between mouthcoating and bitterness suggests that the residual effect of this basic taste may be related to the physical properties of the beer. The persistence of caramel toffee was once again in evidence, related to a clean mouthfeel prominent in BC beers. Hops associated qualities were prominent in CC beers and probably due to residual volatile components from hops. The relationship between these qualities and sour acidic sharp has already been discussed. A lingering odour quality, fruity citrus, appeared positively correlated with mouthdrying suggesting an acidic, 'mouth-puckering' effect which could be associated with the positive, but non-significant, contribution of sour acidic sharp to this factor. The appearance of spicy as an aftertaste quality was probably due to the irritant and very characteristic nature of such volatile qualities.

It has already been observed that if more is to be learnt about the perception of flavour by the human senses, a common vocabulary must be available through which the subtleties of flavour may be communicated. Such was the reasoning behind the introduction of the International System of Beer Flavour Terminology in 1975.[59] However, the vocabulary used in this current research was compiled before the release of the first complete draft of the International System in 1976,[60] and although the structure of the two vocabularies does not permit full comparison, some observations may be made in the light of these results. In the International System, five first tier terms were included under the group term sulphury, i.e. H_2S (rotten), garlic, burnt rubber, DMS (Dimethyl Sulphide) and yeasty. Figure 7 (page 52) shows that results from this research indicate a positive relationship between these qualities in terms of two groupings in odour factor 1 and odour factor 6. As such, these sulphury qualities appeared prominent in the odour of CC beers, and in the odour and aftertaste of beer M in particular. Cross references in the International System, showing inter-relationships between flavour qualities, emphasises the complex nature of flavour. For example 'honey' is included under the first tier term 'sweet' whilst 'syrup' appears under the first tier term 'caramel'. The association suggested here was supported by the relationships shown by these qualities in this research (odour factor 1, Figure 7, page 52).

Reference has already been made to the fact that BC beers have been described as sweeter, blander and less bitter than CC beers[38] (see page 10). Results of this research support this

description in terms of the sweetness and bitterness of the two beer types, but due to lack of definition of the term bland, in this context, no direct comparison can be made. The term bland is included in the International System[60] under the second tier term 'characterless' which appears under the first tier term 'body'. Also included under characterless are the terms empty, flavourless, and inspid - all generally implying lack of flavour. As such, these terms can only be regarded as subjective and somewhat detrimental to any objective sensory analysis of flavour. However, if BC beers are to be described as blander, this implies that, as a group, these beers have less flavour than CC beers. This is substantiated in this research where CC beers had greater intensity in 58 of the 96 qualities. In 15 of these, the differences between beer types were significant. Of the remaining 38 qualities, 3 were not scored for either beer type. BC beers showed greater intensity in 35 qualities, in 7 of which, differences between beer types were significant. Therefore, as a beer type, BC beers had less intensity of flavour over a greater number of qualities and reference has already been made to the relative lack of prominent flavour qualities in BC beers (page 38) when viewed as individual beers. Whether such results are a measure of blandness is left as a matter of conjecture.

Various examples of the application of descriptive sensory analysis to the differentiation between types of beer have already been cited (see page 19).[84-86] In an early study by Swaine and Bell, the flavour profile method was used to assess beers.[97,98] Included in their vocabulary were 3 types of bitterness, chemical, resinous and

metallic. Owing to the simplistic form of data collected by this method, no statistical analysis was possible, but it would seem likely that a factor analysis of this data would have given some indication of the inter-relationship of these facets of bitterness with other qualities. A simplified form of flavour profile assessment was applied to a quality control situation as an algorithm by Wren.[84] A large number of assessors were trained to use a limited vocabulary and associate perceived levels of certain qualities with a pre-determined degree of acceptability. Any beer with qualities above or below a certain intensity level were considered out of specification and were hence unacceptable. Wren later described the application of this technique to evaluate containers for beer.[99] The use of sensory descriptive analysis to differentiate beer types has been demonstrated by Mecredy et al. who compared the flavour profiles of American beers with those of imported beers, finding imported beers to have higher bitterness, hop odour and maltiness.[100] A more recent study by Clapperton and Piggott compared the flavour profiles of ales and lagers, giving an insight into the qualities in which these beer types differed.[101] Using various multivariate techniques, they showed the major sensory flavour qualities of ales to be toffee-like, caramel and burnt compared with the DMS , sulphury and cooked vegetable notes of lagers. The importance of sweet and caramel toffee associations to the overall profile of BC beers examined in this current research has already been discussed, but without details of the ales included in the work of Clapperton and Pigott, no direct comparison of the results is possible.

The models proposed for the flavour of the two beer types and shown in Figure 8, page 54, relies largely on the appropriateness of factor analysis to the interpretation of data from the descriptive analysis. This raises the question of relevance of qualities showing high loadings on factors, a question also raised by Frijters when using Principal Components Analysis to evaluate the texture of chicken meat.[102] Frijters proposed that qualities appearing with high loadings on one factor are probably part of some "latent perceptual continuum". If it is assumed that this also applied to the sensory analysis of flavour, prominent qualities within a single factor may be viewed as part of the same sensory experience. Since the factors were bipolar, this would imply that the sensory experience introduced by CC beers was directly opposed to that introducted by BC beers in factors in which the two beer types differed significantly ($p \leq 0.05$).

In conclusion, the results of this section of the project showed that more significant differences existed in the flavour of beers grouped according to beer type than existed between individual beers. This result justifies the division of beers into types on the basis of flavour differences alone. This objective sensory analysis of beer flavour was designed to be independent of hedonic connotations and as such these results cannot be used as direct indicators of preference for either beer type. Part II of this research was designed to determine preferences for the beers assessed here and reasons for stated preferences in terms of flavour descriptions.

Typification chart of significant differences between beers

ANOVA of the individual beers showed them to differ significantly in terms of fourteen flavour qualities. (page 36). This information was further used to show differences between these beers by constructing a beer typification chart (Table 15(a)).

Table 15(a) Typification chart of significant differences between beers

Beer	Burnt odour Roasted	Onions odour Garlic	Rotten odour putrid	Burnt odour Rubber	Floral odour Fragrant	Sweet odour	Hops odour	Fruity, odour Other	Malty odour	Bitterness FiM Immediate	Burnt AT Rubber	Hops AT	Resinous AT Woody	Bitterness AT Aftertaste	X Row Totals	Y %	Z Beer Type Factor
A BC	1	1	3	3	0	0	0	2	0	1	2	2	0	1	16	10	25
A CC	0	2	7	5	2	3	1	3	2	1	2	4	1	6	39	35	
B BC	10	10	3	8	1	0	0	4	0	1	9	2	0	1	49	32	14
B CC	8	7	7	5	2	0	2	2	0	1	7	4	1	6	52	46	
C BC	1	1	3	3	0	1	0	1	0	2	2	2	0	4	20	13	25
C CC	0	2	7	5	2	4	2	1	2	3	2	4	1	7	42	38	
D BC	1	1	8	3	1	0	0	2	2	1	2	2	0	2	25	16	5
D CC	2	2	2	5	2	0	2	0	0	1	2	4	1	0	23	21	
E BC	1	1	3	3	0	1	0	1	4	1	2	2	0	1	20	13	19
E CC	0	2	7	5	2	3	1	1	5	1	2	4	1	2	36	32	
F BC	1	1	3	3	0	0	0	1	0	1	2	2	0	2	16	10	23
F CC	0	2	7	5	2	0	2	1	2	2	2	4	1	7	37	33	
G BC	1	1	3	3	0	0	0	1	2	2	9	9	0	2	33	21	17
G CC	0	2	7	5	2	0	1	1	0	5	7	5	1	7	43	38	
H BC	1	1	3	3	2	0	0	1	4	1	2	2	0	2	22	14	14
H CC	0	2	7	5	1	1	1	1	5	1	2	4	1	0	31	28	
I BC	1	1	8	8	0	0	0	7	0	3	2	2	0	4	36	23	0
I CC	0	2	2	5	2	0	2	4	2	0	2	4	1	0	26	23	
J BC	1	1	8	8	0	0	0	1	2	4	2	9	0	7	43	28	-7
J CC	0	2	2	5	2	2	1	1	0	0	2	5	1	0	23	21	
K BC	1	1	3	3	0	0	0	1	2	7	2	2	0	4	26	17	25
K CC	0	2	7	5	2	3	2	3	1	8	2	4	1	7	47	42	
L BC	1	1	8	8	0	3	5	1	2	4	2	9	0	6	50	32	-11
L CC	0	2	2	5	1	3	2	2	0	0	2	4	1	0	24	21	
M BC	1	11	11	11	0	4	0	9	6	1	11	9	0	7	81	53	-8
M CC	0	7	7	6	2	3	1	5	1	1	7	5	1	0	46	41	
N BC	1	1	8	8	0	1	0	1	0	3	2	9	0	6	40	26	-5
N CC	0	2	2	5	2	3	1	1	0	0	2	5	1	0	24	21	
O BC	1	10	8	11	1	3	0	3	0	2	9	2	0	6	56	36	-3
O CC	0	7	2	6	4	3	1	2	0	0	7	4	1	0	37	33	
P BC	1	1	8	8	0	0	0	0	2	2	2	2	0	6	32	21	-3
P CC	0	2	2	5	1	0	1	1	1	0	2	4	1	0	20	18	
Q BC	1	1	8	3	0	2	0	1	1	1	2	2	0	0	22	14	13
Q CC	0	2	2	5	1	4	2	3	3	1	2	4	1	0	30	27	
R BC	2	1	8	3	10	1	11	3	6	1	2	11	0	4	63	41	-10
R CC	0	2	2	5	3	4	7	1	1	1	2	6	1	0	35	31	
S BC	2	1	3	3	10	2	0	0	2	9	2	2	11	7	54	35	
S CC	0	2	7	5	4	4	1	1	0	3	2	4	7	0	40	36	1

This chart was constructed in order to examine the extent to which each beer typified its own beer type i.e. BC or CC. The nineteen beers analysed by the trained panel differed significantly in terms of the fourteen flavour qualities shown across the top of the chart. In this chart, each beer A to S, is represented by two rows of numbers. Using beer A as an example, the upper row is the number of BC beers that differed significantly from beer A with respect to each flavour quality in turn; the bottom row is the number of CC beers which differed significantly from beer A with respect to each flavour quality. By summing these numbers across the rows, each beer has a total figure for the number of times it differed significantly from BC beers (Total BC) and a total figure for the number of times it differed significantly from CC beers (Total CC), (Column X in the chart). Because different numbers of BC beers and CC beers were examined, these total figures were converted to percentages of the total possible if that beer had differed significantly from every BC beer or CC beer analysed and in terms of every quality analysed (Column Y). By subtracting the percentage of total BC values from the percentage of total CC values, a beer typification figure is obtained for each beer (Column Z).

It can be seen that the beer typification factors (BT factors) for BC beers are generally larger than those for CC beers, suggesting that more BC beers were typical of their beer type than was the case for CC beers. This in turn suggests that it is easier to obtain a typical BC beer than a typical CC beer. In order to clarify this picture, means for the percentage CC values, percentage BC values

and the BT factors were calculated and these are shown in Table 15(b) below.

Table 15(b) Analysis of beer typification factors for the two beer types.

Item	Mean
% CC values for BC beers	32.5
% BC values for BC beers	17.9
BT factors for BC beers	+ 14.5
% CC values for CC beers	28.5
% BC values for CC beers	32.3
BT factors for CC beers	- 3.25

The means for CC values for BC beers and BC values for CC beers were very similar, indicating that the difference between beer types was consistent. The mean for BC values for BC beers was, however, considerably lower than that for CC values for CC beers, indicating that the difference within BC beers was less than that within CC beers.

This larger difference within CC beers resulted in BT factors for beers of this type often being close to zero, indicating that CC beers differed as much from beers of their own type as from BC beers.

This approach to typification of beers shows that, as a type, BC beers are the more consistent - probably a direct result of the production of a standard 'national' beer; the greater variation shown to exist within CC beers reflects differences in beers of this type developed to satisfy local tastes.

PART II: THE CONSUMER SURVEY

Introduction

Before designing a consumer survey to collect preference data, the population to be sampled and a suitable screening procedure must both be established. In this instance the population of interest were regular drinkers of bitter beers. As no published data regarding the composition of this population were available, the screening procedure was based upon consumption of bitter beers. The procedure used (p 66 et seq) was the same as that reported in other consumer surveys for selecting a sample based primarily on consumption habits related to the food or beverage under examination.[77,103-105] No sampling frame was therefore used for this survey.

The need to include sensory testing of beers by consumers and also the relatively unstable nature of CC beers demanded that a static survey centre be established, at which the beers could remain in a suitable condition for presentation. Establishment of a survey centre also provided facilities for personal interviewing, as a method of collection of both sensory and non-sensory data. The advantages and disadvantages of the interview as a method of data collection have been summarised by Giles.[106] It was considered that with a structured questionnaire and adequate training, interviewers could collect more precise and complete data than could be gathered using more remote methods, such as self completion questionnaires. The use of personal interviewing was therefore regarded as essential for this research.

In addition to a programme of pre-tests of the questionnaire design, interview technique and presentation of beers, (all performed

in the laboratory), a pilot survey was carried out. From the results of this initial survey, substantial changes were made to the methods of collection of sensory data and certain parts of the non-sensory data. Further pre-tests were performed in the laboratory before introducing a revised format for the full consumer survey.

The survey had two main aims:-

1. To determine, by means of sensory tests, preferences of the consumers* for a number of selected beers and also their reasons for the stated preferences.
2. To collect demographic and drinking habits data in order that the sample could be post-stratified in an attempt to explain any trends in preferences.

Experimental

1. Pilot survey (a) Interviewer training

A team of survey personnel was selected primarily from students reading Food and Management Science at this University. The students chosen had received some training in consumer research and sensory analysis. A basic training programme was given, during which discussion groups were held to demonstrate interviewing techniques and to familiarise students with the format of the questionnaire. Particular attention was paid to minimising interviewer bias and a system of standard probes was used to facilitate the uniform questioning of consumers. The team of interviewers was then divided into 3

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*Footnote: Although the term 'respondent' may be considered more appropriate in certain sections of this thesis, for the sake of continuity the term 'consumer' will be used throughout.

groups: screening interviewers, who would approach consumers in the street and accompany suitable subjects back to the survey centre, sensory interviewers who would present selected beers to the consumers and collect relevant sensory data, and finally non-sensory interviewers who would collect demographic and drinking habits data. In addition to the basic training, each group of interviewers received specific training relevant to their particular function.

1. Pilot survey (b) Survey centre, selection and storage of beers

The pilot investigation was carried out in a community hall in a residential area of south east London, adjacent to a busy shopping parade. In order to maximise the chances of obtaining a balanced sample, the survey was undertaken on a Saturday from 10 am to 5.30 pm. As the pilot survey was intended to test procedures and the adequacy of interviewer training, the selection of beers was based simply on availability and ease of collection. The beers therefore consisted of two CC beers (one of which was duplicated) and two BC beers. They were stored in the survey centre for 24 hours before testing which allowed the CC beers to settle. Since they had to be served in the same room in which the interviews were held, a screen was erected to prevent consumers identifying any of them. The beers were coded and served in the red glasses used by the trained assessors (see page 29). Four of the survey personnel were responsible for dispensing the beers and transporting them to the tables where the sensory analyses were performed.

1. Pilot survey (c) Screening interviews

Three interviewers were stationed at pre-determined

locations in the shopping parade with instructions to approach consumers. In order to restrict the inclusion of infrequent beer drinkers quoting exaggerated frequencies, the interviewers were asked to obtain information about the frequency of consumption of beverages other than beer by completing the questionnaire shown in Figure 9.

Figure 9. Questionnaire used by the screening interviewer (pilot survey)

Sex	Approx.Age	Screening Interviewer			Time
Categories		Every day	A few times a week	Occasion-ally	Never
Do you drink tea?					
Do you drink coffee?					
Do you drink bitter beer?					
Do you drink other beers?					
Do you drink spirits?					

Consumers meeting the sampling control, of drinking bitter beers every-day or a few times a week, were invited to test beers and answer further questions at the survey centre. Consumers willing to co-operate were then accompanied back to the centre by the screening interviewer.

1. Pilot survey (d) Collection of demographic data

(see questions 1-5 of the questionnaire in Figure 10A, page 69).

Demographic data relating to sex, age, marital status, income and occupation were collected with the aid of cards showing possible responses, pre-coded to simplify data analysis. After presenting the card to the consumer, the interviewer asked the appropriate

Figure 10. Questionnaire used in pilot survey

A. Demographic Data Questionnaire

Preamble. "Part of the purpose of this survey is to compare consumers' drinking habits with the sorts of beers they prefer, but before we can do this we need to know something about the consumers. These few questions are being asked so that we can compare your likes and dislikes with those of other people. Of course anything you tell us will be treated confidentially".

			Tick
Question 1.	Sex (Tick the appropriate box)	Male	
		Female	
Question 2.	"Are you single, married, widowed, divorced, or separated? (Tick the box)	Single	
		Married	
		Widowed	
		Divorced	
		Separated	
Question 3.	Give Card 1 to the respondent. "Would you mind telling me which of the age groups you fit into please?".	18 - 30	
		31 - 45	
		46 - 60	
		Over 60	
Question 4.	Give Card 2 (Salary) and Card 3 (weekly wages) to respondent. "Would you mind telling me which of the income groups shown on this card you/your head of household fits into please?" (Tick the appropriate box)	A	
		B	
		C	
		D	
		E	
Question 5.	"What is your occupation/the occupation of the head of your household?" (Descriptive answer)	Occupation	

Card 1.
18-30
31-45
46-60
Over 60

Card 2.
A. Under £1500
B. £1550-£2500
C. £2550-£3500
D. £3550-£5000
E. Over £5000

Card 3.
A. Under £30
B. £31 - £50
C. £51 - £70
D. £71 - £100
E. Over £100

Figure 10.(Cont'd)

B. Drinking Habits Questionnaire

		Tick
Question 6. Give Card 4 to the respondent Card 4. A. Everyday B. 2-3 times a week C. At least once a week D. Not very often "Using the groups on this card, how often do you visit a pub at the following times. At Lunch times In the Evenings At Weekends On Special Occasions". (Put letter indicated on card into the appropriate box).	Lunch times	
	Evenings	
	Weekends	
	Special Occasions	
Question 7. "Do you usually go to the same pub?" (Yes/No)	Yes	
	No	

IF YES TO QUESTION 7, ASK QUESTIONS 8, 9, 10, 11 AND 12

Question 8. "Is the pub you visit most frequently, a free house? Is it owned by a brewery?". (Free House/Brewery/Don't know) N.B. A tied house is owned by the brewery. A free house is not tied to one brewery and therefore sells more than one brewery's beer.	Free House	
	Brewery Owned	
	Don't know	
Question 9. "Do you know which beer(s) your pub sells?" (Yes, with name/No). (Name of brewery or beer brand name is acceptable. For free house more than one beer will be sold).	Yes:	
	Name:	
	No.	
Question 10. "Which beer do you usually drink?" (Name/Don't know) (Preferably brand name, if not then bitter/mild/stout and whether keg or draught).	Yes:	
	Name:	
	No.	
Question 11. Give Card 5 to the respondent. Card 5. A. Well B. Slightly C. Not at all "Using the groups on this card could you tell me how well you know the staff of the pub you usually visit?". (Tick appropriate box)	Well	
	Slightly	
	Not at all	

Figure 10. (Cont'd)

		Tick
Question 12. Give Card 6 to the respondent. Card 6. A. Mostly locals B. (A Mixture of locals) (and passing trade) C. Mostly passing trade D. Don't know "We would like to know something about the type of people who visit your pub. Using the groups on this card, what sort of people would you say use your pub most?".	Mostly locals	
	Mixture	
	Mostly passing trade	
	Don't know	

IF NO TO QUESTION 7, ASK QUESTIONS 13 AND 14

Question 13. "Does it matter to you that the pub you visit is a free house?". (Yes/No/Don't know) (Explain what a free house is, where necessary).	Yes	
	No	
	Don't know	
Question 14. "Which beer(s) do you usually drink?". (Name/Don't know) (Preferably brand name, if not then bitter/mild/stout and whether keg, draught, bottled or canned)	Yes: Name:	
	No	

REMAINING QUESTION. TO BE PUT TO ALL RESPONDENTS

Question 15. Give Card 7 to the respondent. Card 7 A. 1 pint or less B. Over 1 but not more than 3 pints C. Over 3 but not more than 6 pints D. Over 6 pints "Using the groups shown on this card please tell me how much beer you drink at these different times:- At Lunch times In the Evenings At Weekends On Special Occasions". (Put letter indicated on card into the appropriate box).	Lunch times	
	Evenings.	
	Weekends	
	Special Occasions	

Figure 10. (Cont'd)

C. Sensory Data Questionnaire

Question 16. "Please smell each of the pairs of beers I place in front of you and tell me if there is any difference in the smell. Please do not sniff too deeply because this can deaden the sense of smell".		Question 17. "Please taste each of the pairs of beers I place in front of you and tell me if there is any difference in the taste. Please make sure that you cover the whole of your tongue with the beer".	
A vs B	Yes No	A vs B	Yes No
A vs C	Yes No	A vs C	Yes No
A vs D	Yes No	A vs D	Yes No
A vs E	Yes No	A vs E	Yes No
B vs C	Yes No	B vs C	Yes No
B vs D	Yes No	B vs D	Yes No
B vs E	Yes No	B vs E	Yes No
C vs D	Yes No	C vs D	Yes No
C vs E	Yes No	C vs E	Yes No
D vs E	Yes No	D vs E	Yes No

Figure 10. (Cont'd)

Question 18. Give the respondent Card 8. Card 8. 9 Like Extremely 8 Like Very Much 7 Like Moderately 6 Like Slightly 5 Neither Like nor Dislike 4 Dislike Slightly 3 Dislike Moderately 2 Dislike Very Much 1 Dislike Extremely "Please smell each beer in turn and tell me whether you like or dislike the smell. Please use the words on this card to describe how much you like or dislike the smell".	Beers	Hedonic Score
	A	
	B	
	C	
	D	
	E	
Question 19. Give the respondent Card 8. Card 8. 9 Like Extremely 8 Like Very Much 7 Like Moderately 6 Like Slightly 5 Neither Like nor Dislike 4 Dislike Slightly 3 Dislike Moderately 2 Dislike Very Much 1 Dislike Extremely "Please taste each beer in turn and tell me whether you like or dislike the taste. Please use the words on this card to describe how much you like or dislike the taste".	Beers	Hedonic Score
	A	
	B	
	C	
	D	
	E	
Question 20. Give sweetness ranking card to respondent. "Please taste each of the beers again and arrange the glasses on the card in front of you so that the sweetest beer is placed here (INDICATE), the next sweetest beer here (INDICATE) and so on. Please make sure that the beer covers the front of your tongue as this is the most sensitive area to sweetness".	1st	
	2nd	
	3rd	
	4th	
	5th	
Question 21. Give bitterness ranking card to respondent. "Please taste each of the beers again and arrange the glasses on the card in front of you so that the most bitter is placed here (INDICATE), the next most bitter beer here (INDICATE) and so on. Please make sure that the beer covers the back of your tongue as this is the most sensitive area to bitterness".	1st	
	2nd	
	3rd	
	4th	
	5th	
Question 22. Give fizziness ranking card to respondent and use fresh beer samples. "Please taste each of the beers again and arrange the glasses on the card in front of you so that the most fizzy is placed here (INDICATE), the next most fizzy beer here (INDICATE) and so on. Please make sure that the whole of your tongue is covered by the beer, especially the front which is the most sensitive area to fizziness.	1st	
	2nd	
	3rd	
	4th	
	5th	

question and recorded the response on the questionnaire shown in Figure 10A,page 69 .

1. Pilot survey (e) Collection of drinking habits data

(see questions 6-15 of the questionnaire in Figure 10B, pages 70, 71).

Data relating to drinking habits of the consumer were collected using the same procedure with cards showing pre-grouped responses to a simple question. The questions were grouped according to whether or not the consumer attended the same pub regularly (Q.7,page 70). All consumers were asked about frequency of visiting a pub (Q.6,page 70), and the amount of beer consumed (Q.15,page 71). Those consumers visiting the same pub regularly were asked about the ownership of the pub (Q.8,page 70), the beers sold by the pub (Q.9,page 70), the beer that the consumer usually drank (Q.10,page 70) the consumer's knowledge of the pub staff (Q.11,page 70) and the type of clientele frequenting the pub (Q.12,page 71). Those consumers not visiting the same pub regularly were questioned about the importance of the ownership of a pub to them (Q.13,page 71) and the identity of the beer the consumer usually drank (Q.14,page 71). It was assumed that the choice of beer of those consumers not using the same pub regularly would not be influenced by the pub in the same manner.

1. Pilot survey (f) Collection of sensory data

(see questions 16-22 of the questionnaire in Figure 10C, pages 72,73).

The ability of consumers to differentiate between beers was tested prior to an assessment of preference. Therefore, a series of difference tests were applied using the paired comparison test. Each consumer was presented with two beers and asked to smell them and to

state if they could perceive any difference in their odours. This procedure was repeated for each pair of beers giving a total of ten paired comparisons (Q.16,page 72). A similar procedure was then used to assess differences in taste between the same pairs of beers (Q.17,page 72).

Relative preference for the aroma of the beers was then determined using a hedonic rating scale. The consumer was presented with one beer at a time and shown a card displaying nine statements describing various degrees of like and dislike. The consumer was then asked to indicate which statement best described his/her assessment of the odour of that beer. The statement chosen was then converted to a score by the sensory interviewer using the scale shown in question 18 page 73. A similar procedure was then used to obtain hedonic scores for the taste of each beer (Q.19,page 73).

The ability of the consumers to differentiate between beers in terms of three prominent sensory qualities was then tested by asking each consumer to rank the five beers in order of (a) sweetness, (b) bitterness, (c) fizziness. (Q.20, 21, 22 page 73).

2. Main survey (a) Amendments to methods

Results from the pilot survey indicated that the methods of data collection had to be amended during the design of the main survey. These amendments are outlined below.

(i) Amendments to collection of demographic data - owing to the inadequacy of responses to the questions regarding the occupation of the consumer, many consumers could not be classified in terms of social class. Interviewers were therefore instructed to obtain a complete

description of the job performed by the consumer.

(ii) Amendments to collection of drinking habits data - the problems experienced during collection of these data (e.g. limitations of consumer knowledge of pub ownership and failure to recall names of beers consumed) required a complete reconstruction of this section of the questionnaire. Since frequency of visiting pubs and amount of beer consumed varied according to the time of day, these questions were subdivided into lunchtime, evening and weekend drinking. A prompt list of 28 bitter beers was also provided in order to remind the consumer of the names of beers frequently consumed. Data relating to pub ownership, knowledge of the type of clientele and pub staff were not collected during the main survey.

(iii) Amendments to collection of sensory data - as the number of beers to be tested during the main survey was greater than that tested during the pilot survey (in order to test a representative selection of each beer type), the fatigue suffered by consumers was reduced by eliminating the comparative difference tests. In addition, reasons for preference in terms of the consumers' flavour descriptions were collected. The ability of the consumer to recognise certain pre-selected prominent flavour qualities in the beers was recorded.

All amendments to the methods of data collection were tested thoroughly in the laboratory before being incorporated into the final questionnaire shown in Figure 12, pages 80-84.

2. Main survey (b) Survey centre, selection and storage of beers

The main consumer survey was performed in office premises over a 3 day period (Thursday-Saturday) in the centre of a suburban shopping centre in outer London. Three separate rooms were available; the first was used to dispense the beers and wash glasses, the second to perform the sensory tests and the third to collect demographic and drinking habits data.

Selection of the nine beers for the survey was based upon the degree to which each beer, previously assessed by the trained assessors, represented each beer type. This was determined using the typification chart described on page 62 . Care was taken during this selection to ensure that beers from both large, national brewing companies and small, local breweries were represented. Details of the selected beers are shown in Table 16.

Table 16. Details of beers selected for the main survey

Beer Code	Beer Type	Brewing Company	Beer Type factor (see page 62)
A*	BC	Large, national, number 1.	25
C	BC	Large, national, number 2.	25
G	BC	Regional, number 1.	17
H	BC	Small, local number 1.	14
K	BC	Small, local number 2.	25
M	CC	Large national number 2.	-8
N	CC	Regional, number 1.	-5
O	CC	Small, local, number 1.	-3
R	CC	Small, local, number 2.	-10

Footnote to Table 16 In the case of BC beers, the greater the beer type factor (see page 62), the more typical it is of the BC beer type. Beers A, C and K had the largest factors as determined by the trained assessors and were therefore considered to be the most typical beers of their type. The smaller factors for beers G and H showed that they are less typical of the BC beer type. In the case of CC beers, the position is complicated by the inherent variability between CC beers (see page 38). However, generally speaking, for a CC beer to differ from the BC beer type it must have a negative beer type factor. All CC beers selected for the main survey therefore had beer type factors which showed them to be atypical of BC beers to approximately the same degree.

* This beer was presented twice to the consumer in order to test reproducibility of response.

Storage and serving of the beers were exactly as described for the pilot survey (page 67).

2. Main survey (c) Interviewer training

The vast majority of interviewers used for the main survey had already taken part in the pilot survey and were given a short retraining programme. Interviewers who had not participated in the pilot survey were given the full training programme as already described (see page 66).

2. Main survey (d) Screening interviews

Four interviewers were positioned in pre-determined locations in and around the shopping centre. Although each interviewer was given a specific population sub-group to approach (male/females under or over 35 years of age), they were instructed to retain frequency of beer drinking as their main sampling control. The format of the questionnaire used during screening is shown in Figure 11, below.

Figure 11. Questionnaire used by screening interviewers in main survey

We are conducting a survey to find out what sort of drinks people enjoy. Would you mind telling me which of the following you drink?	tick
Do you drink tea?	
Do you drink coffee?	
Do you sometimes drink beer?	
Do you drink bottled beers?	
Do you drink beer served from a barrel in a pub?	
Do you drink brown ale?	
Do you drink pale (light) ale?	
Do you drink bitter beer?	
Do you drink lager?	
Which beer would you say-you drink the most of?	
How often would you say you drink beer in a pub?:-	
	Every Day
	2-3 Times a week
	Rarely or never

2. Main survey (e) Collection of demographic data

(see questions 1-5 of the questionnaire in Figure 12A, page 80).

The use of prompt cards as described for the pilot survey (page 68) was adopted throughout the main survey. Cards 1, 2 and 3 were shown in turn to the consumers, a simple question was asked and the response recorded on the questionnaire by the interviewer.

2. Main survey (f) Collection of drinking habits data

(see questions 6-12 of the questionnaire shown in Figure 12B, pages 81, 82).

The same procedure as described in 2(e) above was followed whereby the consumer was shown a card (Cards 4-10) displaying a pre-coded response, the question was asked by the interviewer and the response recorded on the questionnaire by the interviewer.

2. Main survey (g) Collection of sensory data

(see questions 13-18 of the questionnaire shown in Figure 12C, pages 83, 84).

(i) Odour preference data - hedonic response (Q. 13(a)).

The consumer was presented with the ten coded beers and was asked by the interviewer to smell each in turn and indicate which of the phrases on prompt card 11 best described his assessment of the odour of the beer. The response was converted to a score by the interviewer and entered on the questionnaire.

Figure 12. Questionnaire used in Main Survey

A. Demographic Data Questionnaire

Preamble "Part of the purpose of this survey is to compare consumers' drinking habits with the sort of beers they prefer, but before we can do this we need to know something about the consumers themselves. These few questions are asked so that we can compare your likes and dislikes with those of other people. Of course anything you tell us will be treated confidentially.

			Tick
Question 1.	Sex (Tick appropriate box)	Male	
		Female	
Question 2.	"Are you single, married, widowed, divorced or separated?". (Tick box)	Single	
		Married	
		Widowed	
		Divorced	
		Separated	
Question 3.	Give Card 1 to the respondent "Would you mind telling me which of these age groups you fit into please?". (Tick the box)	A	
		B	
		C	
		D	
Question 4.	Give Card 2 (salary) and Card 3 (weekly wage) to respondent "Using the groups on these cards would you tell me the gross income of your household please?". (Tick the box)	A	
		B	
		C	

Card 1.
A. 18-30
B. 31-45
C. 46-60
D. Over 60

Card 2.
A. Below £3000
B. £3000-£5000
C. Above £5000

Card 3.
A. Below £60
B. £60 - £100
C. Above £100

Question 5. "What are the occupations of those contributing to the income of your household?".

(Descriptive answer; ask for an explanation of what the job involves).

Self

Husband/Wife

Others

Figure 12 (Cont'd)

B. Drinking Habits Questionnaire

			Tick
Question 6 Card 4 Lunchtimes A. Every day B. 2-3 times a week C. Rarely or never	Give Card 4 to the respondent "Using the groups on this card, how often do you visit a pub at lunchtimes?" (Tick box)	A B C	
Question 7 Card 5 Evenings A. Every day B. 2-3 times a week C. Rarely or never	Give Card 5 to the respondent "Using the groups on this card, how often do you visit a pub in the evenings?" (Tick box)	A B C	
Question 8 Card 6 Weekends A. Every weekend B. Most weekends C. Rarely or never	Give Card 6 to the respondent "Using the groups on this card, how often do you visit a pub at the weekends?" (Tick box)	A B C	
Question 9 Card 7 Lunchtimes A. 1 pint or less B. Over 1 pint but not more than 3 pints C. Over 3 pints but not more than 6 pints D. Over 6 pints	Give Card 7 to the respondent "Using the groups on this card, how much beer do you drink at lunchtimes?" (Tick box)	A B C D	
Question 10 Card 8 Evenings A. 1 pint or less B. Over 1 pint but not more than 3 pints C. Over 3 pints but not more than 6 pints D. Over 6 pints	Give Card 8 to the respondent "Using the groups on this card, how much beer do you drink in the evenings?" (Tick box)	A B C D	

Figure 12 (Cont'd)

Question 11

Give Card 9 to the respondent

"Using the groups on this card, how much beer do you drink in total at weekends?"
(Tick box)

Card 9

Weekends

A. 1 pint or less
B. Over 1 pint but not more than 3 pints
C. Over 3 pints but not more than 6 pints
D. Over 6 pints

	Tick
A	
B	
C	
D	

Question 12

"Which beers do you usually drink?"

If the respondent cannot recall the name of the beers, give Card 10

If the beers do not appear on Card 10, enter the name at the end of the list

Card 10

See list opposite

Fullers Bitter	
Fullers London Pride	
Fullers ESB	
Ind Coope Bitter	
Double Diamond	
Watneys Special	
Watneys Red	
Charringtons IPA	
Bass Draught	
Worthington E	
Youngs Bitter	
Youngs Special Bitter	
Courage IPA	
John Courage	
Courage Tavern	
Courage Directors Bitter	
Gales Bitter	
Gales Keg	
Whitbread Trophy	
Whitbread Tankard	
Greene King IPA	
Greene King Abbot	
Greene King Keg	
Youngers Tartan	
McEwans Export	
Tolly Bitter	
Tolly Conquest	
Ruddles County	

Figure 12 (Cont'd)

C. Sensory Data Questionnaire

Question 13(a) Give the respondent Card 11

Card 11

9* — Like Extremely
8 — Like Very Much
7 — Like Moderately
6 — Like Slightly
5 — Neither Like nor Dislike
4 — Dislike Slightly
3 — Dislike Moderately
2 — Dislike Very Much
1 — Dislike Extremely

"Please smell each beer in turn and tell me whether you like or dislike the smell. Please use the words on this card to describe how much you like or dislike the smell."

*These scores do not appear on Card 11 given to the consumer

Colour Code	Hedonic Score	Reasons for Preference
Stripe		
Black		
Blue		
Red		
Yellow		
Brown		
Grey		
Orange		
White		
Green		

Question 13(b) After the respondent has answered the first part of this question for one beer, ask the second part of the question before going on to the next sample.

"Please tell me why you ___*___ the smell of this beer."

*Insert the term used by the respondent to describe how much they liked or disliked the smell of that beer

Question 14 Give the respondent Card 12. Present each beer in turn.

"Which of the terms on this card would you use to describe the smell of this beer?"

Qualities on Card 12 \ Beers	Stripe	Black	Blue	Red	Yellow	Brown	Grey	Orange	White	Green
Sweet										
Fruity										
Caramel Toffee Malty										
Like Flowers										
Sharp, Sour										
Burnt										
Rotten										

Question 15 Give the respondent Cards 13-19.

Cards 13-19

13. Sweet
14. Fruity
15. Caramel Toffee Malty
16. Like Flowers
17. Sharp, Sour
18. Burnt
19. Rotten

"When you drink beer which of the smells written on these cards is the most important to you?"

And which is the next most important, etc., etc.

No cards are to be ranked equally.

Order of Importance	
1st.	
2nd.	
3rd.	
4th.	
5th.	
6th.	
7th.	

Figure 12 (Cont'd)

Question 16(a) Give the respondent Card 11

Card 11

9* — Like Extremely
8 — Like Very Much
7 — Like Moderately
6 — Like Slightly
5 — Neither Like nor Dislike
4 — Dislike Slightly
3 — Dislike Moderately
2 — Dislike Very Much
1 — Dislike Extremely

"Please taste each beer in turn and tell me whether you like or dislike the taste. Please use the words on this card to describe how much you like or dislike the taste."

*These scores do not appear on Card 11 given to the consumer.

Colour Code	Hedonic Score	Reasons for Preference
Stripe		
Black		
Blue		
Red		
Yellow		
Brown		
Grey		
Orange		
White		
Green		

Question 16(b) After the respondent has answered the first part of this question for one beer, ask the second part of the question before going on to the next sample.

"Please tell me why you ___*___ the taste of this beer."

*Insert the term used by the respondent to describe how much they liked or disliked the taste of that beer.

Question 17 Give the respondent Card 20. Present each beer in turn.

"Which of the terms on this card would you use to describe the taste of this beer?"

Qualities on Card 20 \ Beers	Stripe	Black	Blue	Red	Yellow	Brown	Grey	Orange	White	Green
Sweet										
Caramel Toffee Malty										
Like Flowers										
Sharp , Sour										
Burnt										
Bitter										
Fizzy										
Smooth										

Question 18 Give the respondent Cards 21-27.

Cards 21-27

21. Sweet
22. Caramel Toffee Malty
23. Like Flowers
24. Sharp, Sour
25. Bitterness
26. Fizzy
27. Smooth

"When you drink beer which of the tastes written on these cards is the most important to you?"

And which is the next most important?

No cards to be ranked equally.

Order of Importance	
1st.	
2nd.	
3rd.	
4th.	
5th.	
6th.	
7th.	

(ii) Odour preference data - reasons for hedonic response (Q. 13(b)).

Having collected a hedonic response for the odour of a beer, the interviewer then asked the respondent to describe, in his own words, why he had liked or disliked the odour. The exact words used by the consumer were recorded on the questionnaire by the interviewer.

(iii) Recognition of pre-selected odour qualities in the beers (Q.14).

The consumers were again presented with the ten beers and were given Card 12 showing seven pre-selected odour qualities. These had been selected on the basis of their relative importance to the differentiation between individual beers and beer types by the trained assessors in Part I, where nine odour qualities in which the independent beers differed significantly ($p \leq 0.05$) had been identified (page 35). Consumers were asked to smell each beer in turn and to say which of the odour qualities they could detect and recognise in each beer. The interviewer recorded these on the questionnaire.

(iv) Ranking pre-selected odour qualities in order of importance to the consumer (Q.15).

The consumer was given seven prompt cards (Cards 13-19) each displaying one of the pre-selected qualities used in 2(g)(iii). The interviewer asked the consumer to rank the odour qualities in order of importance to him; this rank order was recorded on the questionnaire by the interviewer.

(v) Taste preference data - hedonic response (Q.16(a)).

These data were collected in the same ways as for the odour preference data (2(g)(i)) but in this instance fresh samples of each beer were tasted and a taste preference recorded.

(vi) Taste preference data - reasons for hedonic response (Q. 16(b)).

These data were collected in the same way as for the odour preference data (2(g)(ii)) but in this case consumers were asked to give reasons for their hedonic response to the taste of the beers.

(vii) Recognition of pre-selected taste qualities in the beers (Q. 17).

The consumers were presented with fresh samples of the ten beers together with prompt card 20 showing seven pre-selected taste qualities. These had been selected in a similar way as described for the pre-selected odour qualities (2(g)(iii)) but included flavour-in-mouth and aftertaste qualities in which the beers had been found to differ significantly ($P \leq 0.05$) (see Part I, page 35). The consumers were asked to taste each beer in turn and to say which of the seven taste qualities they could detect and recognise in each beer. The interviewer recorded these on the questionnaire.

(viii) Ranking pre-selected taste qualities in order of importance to the consumer (Q. 18)

The consumer was given seven prompt cards (cards 21-27) each displaying one of the pre-selected taste qualities(2(g)(vii)). The interviewer then asked the consumer to rank the taste qualities in order of importance; this rank order was then recorded on the questionnaire by the interviewer.

RESULTS AND DISCUSSION: MAIN CONSUMER SURVEY

A. Demographic composition of sample (see Questions 1-5, page 80)

The demographic composition of the sample of 207 consumers is tabulated in Tables 17-21, below.

Table 17. Sex distribution (Question 1, page 80)

Sex	Number	Percentage of sample
Male	201	97.1
Female	6	2.9

Table 18. Marital status distribution (Question 2, page 80)

Marital Status	Number	Percentage of sample
Single	141	68.1
Married	50	24.2
Widowed	1	0.5
Divorced	5	2.4
Separated	10	4.8

Table 19. Age distribution (Question 3, page 80)

Age (years)	Number	Percentage of sample
Under 30	169	81.6
31-45	27	13.0
46-60	9	4.3
Over 60	2	1.0

Table 20. Income distribution (Question 4, page 80)

Income	Number	Percentage of sample
Below £3,000	45	21.7
£3,000 - £5,000	74	35.7
Above £5,000	86	41.5
No response	2	1.0

Table 21. Social class distribution (Question 5, page 80)

Social Class*	Number	Percentage of sample
I	16	7.7
II	39	18.3
III N	41	19.8
III M	47	22.7
IV	22	10.7
V	5	2.4
Economically inactive +	37	17.9

Footnote to Table 21

* The social class of consumers was determined solely from descriptions of occupation given by the consumer in response to Question 5, page 80 . The method of classification was that used by the office of population censuses and surveys.[107]

In subsequent analyses, social groups were combined in order to achieve a large minimum cell size. In these instances social classes were combined as follows:-

I + II = 26.5% of the sample
IIIM + IIIN = 42.5% of the sample
IV + V + economically inactive = 31.0% of the sample

\+ This group included consumers who were unemployed, retired or in the armed services.

The predominant sampling controls in force during this survey were related to the drinking habits of the consumer. This led to a disproportionate sample with respect to sex distribution (Table 17), marital status distribution (Table 18) and age distribution (Table 19). The sample distribution was therefore biased towards single males aged between 18 and 30 years. A profile of the UK bitter beer drinking population (1973)[108] shows a similar bias (see Table 22).

Table 22. A profile of the UK bitter beer drinking population[108]

Classification	Group	% of drinkers (population)	% of consumption (population)
SEX	Male	85	95
	Female	15	5
AGE	16-34	44	47
	35-44	17	17
	45+	39	36
SOCIAL CLASS	I, II, IIN	32	26
	IIIM, IV V	68	74

Comparison of this table with our sample, still shows that we had a bias towards the younger male drinker in social classes I, II and IIIN. However, comparison of the structure of our sample with that of the UK population shows a greater agreement for both social class and income groups. (see Table 23, page 89).

It may therefore be concluded that the age and sex structure of our sample more closely resembles that of the UK bitter beer drinking population whereas the social class and income structure more closely resembles that of the UK population. However the bias of the sample restricts investigation of the influence of all but the income groups and social class on any trends in preference data.

Table 23. Comparison of (a) social class and (b) income distribution of sample and population

(a) Social Class

Social Classes	Sample(%)	Population(%) (1971)*
I + II	26.5	20.4
IIIM + IIIN	42.5	44.8
IV + V + economically inactive	31.0	34.8
	100	100

* These figures were calculated from the 1971 census[109] and represent the breakdown of the male population.

(b) Income Groups

Income groups	Sample(%)	Population(%) (1977)**
< £3,000 pa	21.7	32.9
£3,000 - £5,000 pa	35.7	27.6
> £5,000 pa	41.5	39.5

** Source: Family Expenditure Survey, Department of Employment.[110]

B. Drinking habits of the sample (see Questions 6-12, pages 81-82).

The drinking habits of the sample are shown in Tables 24 and 25, page 90.

Division of the sample according to predominant beer type consumed was obtained by recording details of the actual beers regularly consumed by respondents (Q.12, page 82). About 80% of the sample regularly drank one or other of the two beer types, the remaining 20% consumed both types regularly, (see Table 26, page 90).

Table 24. Frequency of pub visiting (Questions 6-8, page 81)

Frequency	Lunchtimes (Q. 6, p. 81) No.	Lunchtimes (Q. 6, p. 81) % of Sample	Evenings (Q. 7, p. 81) No.	Evenings (Q. 7, p. 81) % of Sample
Every day	40	19.3	47	22.7
2-3 times a week	84	40.6	139	67.1
Rarely or never	83	40.1	21	10.1

Frequency	Weekends (Q. 8, p. 81) No.	Weekends (Q. 8, p. 81) % of Sample
Every weekend	130	62.8
Most weekends	63	30.4
Rarely or never	14	6.8

Table 25. Amounts consumed (Questions 9-11, pages 81-82)

Amount (pints)	Lunchtimes (Q. 9, p. 81) No.	Lunchtimes (Q. 9, p. 81) % of Sample	Evenings (Q. 10, p. 81) No.	Evenings (Q. 10, p. 81) % of Sample	Weekends (Q. 11, p. 82) No.	Weekends (Q. 11, p. 82) % of Sample
1 or less	69	33.3	7	3.4	4	1.9
Over1but less than 3	111	53.6	84	40.6	20	9.7
Over 3 but less than 6	26	12.6	90	43.5	55	26.6
Over 6	1	0.5	26	12.6	128	61.8

Table 26. Predominant beer type consumed (Question 12, page 82)

Beer Type	Number	Percentage of sample
Mostly CC beers	93	44.9
Mostly BC beers	71	34.3
Selection of both	43	20.8

C. Sensory Data

Data from taste assessments (Questions 16-18, page 84) were analysed in an identical manner to those from odour assessments (Questions 13-15, page 83), and therefore the results are presented and discussed together.

C. (i) Hedonic response to odour (Question 13(a)) and to taste (Question 16(a))

Distribution of the hedonic scores for each beer covering the entire scale are shown in Table 27(a) (odour) and 27(b) (taste).

Table 27(a) Percentage of sample using the nine divisions of the hedonic scale for odour of selected beers

Hedonic response	Score	Beers									
		A_1	A_2	C	G	H	K	M	N	O	R
Dislike extremely	1	1.0	1.4	1.0	2.9	9.7	1.4	23.7	4.8	10.1	4.3
Dislike very much	2	3.9	3.4	1.0	4.8	12.6	7.2	15.0	9.7	12.1	9.2
Dislike moderately	3	7.7	6.8	5.8	8.2	11.1	13.0	8.7	9.7	12.6	7.7
Dislike slightly	4	7.7	14.5	10.1	11.1	15.9	13.5	9.7	13.5	16.4	17.9
Neither like nor dislike	5	25.6	27.1	21.3	23.7	14.0	23.7	4.8	23.2	18.4	12.6
Like slightly	6	23.2	13.5	17.9	20.5	11.6	10.1	7.2	17.9	14.0	15.9
Like moderately	7	17.9	24.2	31.9	16.9	15.9	21.3	15.0	14.0	10.1	17.4
Like very much	8	11.6	8.2	10.1	10.6	8.2	9.2	14.0	5.8	5.3	12.1
Like extremely	9	1.4	1.0	1.0	1.4	1.0	0.5	1.9	1.4	1.0	2.9

Footnote to Table 27(a) Beers coded in red = BC beers
Beers coded in green = CC beers

Table 27(b) Percentage of sample using the nine divisions of the hedonic scale for taste of selected beers

Hedonic response	Score	Beers									
		A_1	A_2	C	G	H	K	M	N	O	R
Dislike extremely	1	2.4	2.4	1.9	1.9	4.3	3.9	31.9	13.0	10.6	15.0
Dislike very much	2	5.3	6.3	5.8	5.3	7.7	9.2	15.9	17.4	14.5	15.5
Dislike moderately	3	9.7	6.3	11.1	5.8	10.6	8.7	7.7	16.9	10.6	13.5
Dislike slightly	4	13.5	15.9	9.7	12.6	18.8	12.1	9.2	13.0	11.6	13.5
Neither like nor dislike	5	18.4	12.1	7.7	11.1	11.6	7.7	1.9	8.2	14.0	5.8
Like slightly	6	14.5	16.4	15.5	19.8	19.8	20.8	6.8	10.6	12.1	11.1
Like moderately	7	21.7	22.7	33.8	22.7	15.9	19.3	12.6	13.0	17.4	11.6
Like very much	8	12.6	13.0	12.1	18.4	8.7	17.4	9.7	6.8	7.2	9.7
Like extremely	9	1.9	4.8	2.4	2.4	2.4	1.0	4.3	1.0	1.9	4.3

Footnote to Table 27(b) Beers coded in red = BC beers
Beers coded in green = CC beers

In order to determine whether a significant preference existed for the odour and taste of any of the selected beers, an ANOVA was performed on (a) the odour scores and (b) the taste scores with individual beers nested within beer types (as described on page 33). The BMDP computer programme P2V[92] was used for this analysis. The manner in which preferences

for the individual beers varied was determined using the least significant difference test.[93] Results are shown in Table 28(a) and (b).

Table 28(a) Variation in hedonic responses for the odour of the selected beers

Beers	C	A_1	A_2	G	R	K	N	H	O	M
Means of hedonic scores	5.87	5.61	5.46	5.38	5.20	5.15	4.88	4.58	4.36	4.20
LSD test $p \leq 0.5$	PREFERRED MOST								PREFERRED LEAST	
Beer types	The odour of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beers									

Table 28(b) Variation in hedonic responses for the taste of the selected beers

Beers	G	C	A_2	A_1	K	H	O	R	N	M
Means of hedonic scores	5.82	5.72	5.63	5.45	5.43	5.07	4.58	4.34	4.10	3.78
LSD test $p \leq 0.5$	PREFERRED MOST								PREFERRED LEAST	
Beer types	The taste of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beers									

Footnote to Table 28 Beers underlined by the same line showed no significant difference in hedonic scores ($p \leq 0.05$); beers not underlined by the same line differed significantly in their hedonic scores ($p \leq 0.05$). BC beers = red : CC beers = green.

A significant variation was found between both beer types and also between certain individual beers in terms of both odour and taste preferences, and therefore it was necessary to determine whether this variation was due to the sensory qualities of the beers or whether it was a

function of the demographic composition or drinking habits of the sample. This problem was approached in two ways:-

(a) Multiway contingency tables were constructed in order to measure any interaction between preference data relating to the odour and taste of the beers, and selected demographic and drinking habits data.

(b) Three separate ANOVA's were carried out on both the odour and taste preference data using three sub-samples formed by sub-dividing the entire sample according to the type of beer normally consumed (see Table 26, page 90). These analyses were performed in order to determine the specific effect of the type of beer regularly consumed on variations in odour and taste preferences.

(a) Multiway Contingency Tables

Four series of screening effects were tested in order to determine whether an appropriate model could be found to define the relationship between odour or taste preference scores, demographic data and drinking habits data. A BMDP programme, P3F[111] was used for this analysis. The four series of screening tests are shown in Table 29, page 94 . Series 1 was designed to screen the effect of social class, income and predominant beer type consumed on both the odour and taste preference score for each beer. For example, if the predominant type of beer consumed influenced preferences for, say, the odour of a particular beer, this would be reflected in the frequency of use of a certain section of the hedonic scale and a significant interaction would be shown between these variables. In order to prevent small frequencies occuring in certain cells on the table, social classes were grouped together as shown in Table 21, page 87. As the sample was disproportionate in terms of age, sex and marital status, these demographic criteria were not included in the analysis. Series 2, 3 and 4 were designed to screen the effect of the predominant beer type consumed and drinking habits (in terms of frequency and amounts consumed) on (a) the odour and (b) the taste preference scores for each beer.

Table 29 Composition of the variable used in the screening tests in the multiway contingency tables

Series 1

Predominant beer type consumed	Social* class	Income	frequency of use of hedonic scores for beer A_1 ..... n
3 classes	3 classes	3 classes	9 classes
CC beers BC beers either	I + II IIIN + IIIM 4 + 5 + others	(< £3000) (£3000-£5000) (> £5000)	1 2 3 4 5 6 7 8 9

* see p. 87 for explanation of groupings

Series 2

Predominant beer type consumed	Lunchtime drinking frequency	Amount consumed at lunchtimes	frequency of use of hedonic scores for beer A_1 ..... n
3 classes	3 classes	4 classes	9 classes
CC beers BC beers either	everyday 2-3 times/week rarely or never	< 1 pint 1-3 pints 3-6 pints > 6 pints	1 2 3 4 5 6 7 8 9

Series 3

Predominant beer type consumed	Evening drinking frequency	Amount consumed in evening	frequency of use of hedonic scores for beer A_1 ..... n
3 classes	3 classes	4 classes	9 classes
CC beers BC beers either	everyday 2-3 times/week rarely or never	< 1 pint 1-3 pints 3-6 pints > 6 pints	1 2 3 4 5 6 7 8 9

Series 4

Predominant beer type consumed	Weekend drinking frequency	Amount consumed at weekend	frequency of use of hedonic scores for beer A_1 ..... n
3 classes	3 classes	4 classes	9 classes
CC beers BC beers either	every weekend most weekends rarely or never	< 1 pint 1-3 pints 3-6 pints > 6 pints	1 2 3 4 5 6 7 8 9

Two separate series of multiway contingency tables were constructed for (a) odour and (b) taste preference data.

Results indicated that no significant interactions existed between odour or taste preference scores and any of the other variables tested ($p \leq 0.05$); the lowest probability values for any beer for two-variable interactions are shown in Table 30.

Table 30 Results of multiway contingency analysis of variables affecting odour and taste preferences (two variable interactions involving preference scores)

Series 1.

Variable	Lowest probability value for any beer	
	Odour	Taste
preference x income	0.64	0.21
preference x social class	0.48	0.74
preference x beer type regularly consumed	0.12	0.13

Series 1, 2 and 3.

Variables	Lowest probability value for any beer					
	Lunchtimes		Evenings		Weekends	
	Odour	Taste	Odour	Taste	Odour	Taste
preference x quantity consumed	0.34	0.71	0.72	0.74	0.88	0.86
preference x frequency of pub visiting	0.37	0.63	0.34	0.42	0.65	0.59

Footnote to Table 30 In order for a relationship to be significant ($p \leq 0.05$), the probability value must be less than 0.05.

No three-variable or four-variable interactions with odour or taste preference scores were significant ($p \leq 0.05$) for any beer. This indicated that both the odour and taste preference scores were independent of these variables and thus the significant variation in preferences already shown (Table 28 p. 92) between beers and beer types, could not be explained in terms of demographic or drinking habits data. Nevertheless, ANOVA was still

performed on the sub-divided sample in order to observe any variation in preference attributable to beer type regularly consumed.

(b) ANOVA on sub-divided sample

The sample was divided according to the type of beer normally consumed (Question 12, page 82 and Table 26, page 90) and an ANOVA was performed (as described on page 33) on (a) the odour and (b) the taste scores from each sub-sample. Results are shown in Tables 31 and 32 on pages 97, 98.

The odour data showed that no significant preference for the odour of either beer type was shown by regular CC beer drinkers nor by indiscriminate drinkers. However regular BC beer drinkers did show a significant preference for the odour of BC beers. Of the individual beers, beer R (a CC beer) shows the greatest variation in mean hedonic scores, receiving highest ratings from CC beer drinkers (mean hedonic score 5.47) and lowest ratings from BC beer drinkers (mean hedonic score 4.61). BC beer C consistently received the highest mean hedonic score from all three sub-samples of consumers whereas CC beer M received the lowest mean score from two of the sub-samples i.e. BC beer drinkers and indiscriminate drinkers; CC beer O received the lowest mean hedonic score from CC beer drinkers. BC beer H consistently received the lowest mean hedonic score for BC beers from all three sub-samples.

The taste data revealed that a significant preference for the taste of BC beers was shown by all sub-samples and the preference for this beer type by regular BC beer drinkers was absolute, i.e. the taste of all BC beers being preferred to that of all CC beers. No significant preference for the taste of any individual beers was shown by regular CC beer drinkers. With one exception (beers O, H) the order of beers in terms of mean hedonic scores was the same for BC beer drinkers and indiscriminate drinkers.

Distributions of hedonic scores for the beers indicated considerable variation in preferences for both odour and taste (Tables

Table 31(a) Variation in hedonic response of CC beer drinkers to odour of selected beers

Beers	C	R	A_1	A_2	N	G	K	H	M	O
Means of hedonic scores	5.71	5.47	5.41	5.34	5.18	5.12	4.95	4.93	4.86	4.67
LSD test $p \leq 0.05$	PREFERRED MOST ... PREFERRED LEAST									
Beer types	(No significant preference ($p \leq 0.05$)									

Table 31(b) Variation in hedonic response of BC beer drinkers to odour of selected beers

Beers	C	A_1	G	A_2	K	R	N	H	O	M
Means of hedonic scores	5.86	5.78	5.62	5.58	5.13	4.61	4.55	4.17	3.96	3.49
LSD test $p \leq 0.05$	PREFERRED MOST ... PREFERRED LEAST									
Beer types	The odour of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beers									

Table 31(c) Variation in hedonic response of indiscriminate beer drinkers to odour of selected beers

Beers	C	A_1	K	R	G	A_2	N	H	O	M
Means of hedonic scores	6.26	5.77	5.63	5.61	5.56	5.54	4.77	4.49	4.37	3.95
LSD test $p \leq 0.05$	PREFERRED MOST ... PREFERRED LEAST									
Beer types	No significant preference									

Footnote to Table 31 Beers underlined by the same line showed no significant difference in hedonic scores ($p \leq 0.05$); beers not underlined by the same line differed significantly in their hedonic ratings ($p \leq 0.05$). BC beers = red; CC beers = green.

Table 32(a) Variation in hedonic responses of CC beer drinkers to taste of selected beers

Beers	G	K	C	H	A_2	O	A_1	R	M	N
Means of hedonic scores	5.58	5.44	5.44	4.99	4.91	4.88	4.86	4.84	4.84	4.71
LSD test $p \leq 0.05$	No significant preference between beers ($p \leq 0.05$)									
Beer types	The taste of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beer									

Table 32(b) Variation in hedonic responses of BC beer drinkers to taste of selected beers

Beers	A_2	G	C	A_1	K	H	O	R	N	M
Means of hedonic scores	6.10	5.85	5.78	5.76	5.49	5.25	3.83	3.62	3.39	2.62
LSD test $p \leq 0.05$	———	———					———			———
Beer types	The taste of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beers									

Table 32(c) Variation in hedonic responses of indiscriminate beer drinkers to taste of selected beers

Beers	A_2	G	C	A_1	K	O	H	R	N	M
Means of hedonic scores	6.42	6.30	6.23	6.21	5.30	5.14	4.93	4.44	3.93	3.42
LSD test $p \leq 0.05$	———	———	———	———			———	———	———	———
Beer types	The taste of BC beers was preferred significantly ($p \leq 0.05$) to that of CC beers									

Footnote to Table 32 Beers underlined by the same line showed no significant difference in hedonic scores ($p \leq 0.05$); beers not underlined by the same line differed significantly in their hedonic ratings ($p \leq 0.05$). BC beers = red : CC beers = green.

27(a) and 27(b)p. 91). For odour (Table 27(a)), the vast majority of consumers scored most beers, and particularly A1 and G, around the mid-point of the scale, in what may be regarded a neutral zone. In this zone, hedonic responses were represented by the phrases like slightly, dislike slightly or neither like nor dislike. For beers R and H, the distribution of hedonic scores was spread relatively evenly over the whole scale showing a more intense response to the odour of these beers by those consumers using the extremes of the scale. The greatest intensity and diversity of hedonic response was shown for beer M. For this beer, only 21.7% of the sample scored in the neutral zone (compared with 49.3% who used scores in this zone to express their hedonic response to beer C, the beer with the highest mean hedonic score) while 47.4% disliked the beer and 30.9% liked the beer. Therefore, although biased towards the dislike end of the hedonic scale, there is definite evidence of a bimodal distribution of responses for the odour of beer M.

In the case of taste (Table 27(b)p. 91) The preference for BC beers was far stronger than was the case for odour; this being reflected in the greater use of the like portion of the scale for BC beers. All four CC beers exhibited some degree of bimodality with a greater use of the dislike portion of the scale. There was therefore less tendency to use scores in the neutral zone when rating beers for taste. This increased strength of hedonic response is reflected in a stronger preference for the taste of BC beers and greater bimodality in the responses to CC beers.

Various workers have demonstrated the importance of such bimodal distributions of preference data.[112,113] Benson has shown that examination of distributions often gives a useful indication of the potential success of a product on the market.[112] Referring to the 'popularity fallacy', Benson claims that brands which show high scores in the neutral zone, and which are shown to be preferred on average, are often less successful than brands which offer something distinctive and evoke a

strong hedonic response, although appealing to a minority of consumers. In this research, beer M had the lowest mean hedonic score for both odour and taste preferences when the whole consumer sample was analysed. This means that it was the least preferred beer which would suggest a low potential for market success. However, this would not have been true either for the 30.9% of the sample who showed a positive liking for its odour or for the 26.6% who showed a positive liking for its taste. If this trend were reflected in the beer drinking population, (at least 26% of which showed a positive liking for both the odour and taste of this beer), then provided that this target population could be readily located, beer M would stand a good chance of success. Further work by Kuen and Day has shown that if reasons for bimodality in distributions of preference data can be determined, such information can contribute to the prediction of the success of a product.[113] The reasons for the bimodality shown by beer M will be discussed later (see page 128).

Despite the above observation, these preference data were treated in this analysis as though they were normally distributed and were therefore assumed to comply with the requirements of parametric statistical analysis.[114] This is justified in analysis of data of this type and can be substantiated by numerous references, e.g.[115-120]. However, inspection of the frequency distributions (Tables 27(a) and 27(b) p. 91) reveals that considerable variation existed from beer to beer - such variation rendering application of transformations ineffective. These data were therefore subjected to non-parametric analysis using Friedmann's method[121] and the Chi square test[122] in order to check the effect of this variation on the results already described (and obtained using parametric methods). The results of these non-parametric analyses are shown in Table 33, page 101 and Table 34, page 102. Comparison with those from the parametric ANOVA (Tables 28, 31, 32, pages 92, 97, 98 respectively) show only a slight variation in the rank order of beers. In each ANOVA performed, 45 comparisons were possible between different pairs of beers.

Table 33 Variation in hedonic response to odour of selected beers using non-parametric analysis

Table 33(a) whole sample

Beers	C	A_1	A_2	G	R	K	N	H	O	M
Rank sums	1357.0	1294.5	1245.5	1206.5	1185.0	1150.0	1070.0	1006.5	938.0	927.0
chi^2 test ($p \leq 0.05$)										

Table 33(b) CC beer drinkers

Beers	C	R	A_1	A_2	N	G	M	H	K	O
Rank sums	584.5	557.0	544.5	536.5	510.0	501.5	485.0	478.5	474.0	443.5
chi^2 test ($p \leq 0.05$)										

Table 33(c) BC beer drinkers

Beers	A_1	C	A_2	G	K	N	R	H	O	M
Rank sums	484.0	470.0	456.0	451.5	414.0	360.0	355.0	331.0	310.0	272.5
chi^2 test ($p \leq 0.05$)										

Table 33(d) Indiscriminate drinkers

Beers	C	R	K	A_1	G	A_2	N	H	O	M
Rank sums	302.0	272.5	267.0	266.0	253.5	253.0	200.0	197.0	184.5	169.5
chi^2 test ($p \leq 0.05$)										

Footnote to Table 33 Beers underlined by the same line showed no significant difference in hedonic scores, ($p \leq 0.05$); beers not underlined by the same line differed significantly in their hedonic ratings ($p \leq 0.05$). BC beers = red ; CC beers = green.

Table 34 Variation in hedonic response to taste of selected beers using non-parametric analysis

Table 34(a) whole sample

Beers	G	C	A_2	K	A_1	H	O	R	N	M
Rank sums	1360.0	1311.5	1303.5	1270.0	1222.5	1148.0	1033.0	968.0	914.5	853.0
chi^2 test ($p \leq 0.05$)										

Table 34(b) CC beer drinkers

Beers	G	K	C	O	M	H	A_2	A_1	R	N
Rank sums	582.5	564.0	556.0	501.5	501.0	498.5	489.5	477.0	476.5	468.5
chi^2 test ($p \leq 0.05$)										

Table 34(c) BC beer drinkers

Beers	A_2	G	C	A_1	K	H	O	R	N	M
Rank sums	512.0	483.5	471.5	464.0	464.0	425.0	308.5	293.0	277.5	206.0
chi^2 test ($p \leq 0.05$)										

Table 34(d) Indiscriminate drinkers

Beers	A_2	G	C	A_1	K	H	O	R	N	M
Rank sums	302.0	294.0	284.0	281.5	242.5	225.0	223.0	198.5	168.5	146.0
chi^2 test ($p \leq 0.05$)										

Footnote to Table 34 Beers underlined by the same line showed no significant difference in hedonic scores ($p \leq 0.05$); beers not underlined by the same line differed significantly in their hedonic ratings ($p \leq 0.05$). BC beers = red; CC beers = green

From the ANOVA's on the entire sample and the sub-divided sample, a total of 180 comparisons were therefore possible for odour and a further 180 for taste. When the parametric and non-parametric methods were compared, a significant variation ($p \leq 0.05$) was shown between the two methods in only 18 of these 180 comparisons for odour (Table 35(a), below) and in only 19 of the 180 comparisons for taste (Table 35(b), page 104).

Table 35(a) Significant differences between parametric and non-parametric ANOVA of odour preference scores

Beers	Sample	Variation from Parametric ANOVA	Variation from Non-Parametric ANOVA
A_1 v G	X	*	
A_1 v H	X	*	
A_1 v K	Y		*
A_1 v M	X	*	
A_1 v R	W	*	
A_2 v C	W	*	
A_2 v G	X	*	
A_2 v H	X	*	
A_2 v K	X	*	
A_2 v M	X	*	
A_2 v N	Z		*
C v N	X		*
G v N	Z		*
G v R	X	*	
K v R	Y		*
M v N	Z	*	
N v O	X		*
N v R	W		*

Footnote to Table 35(a)

* indicates significant differences between beers ($p \leq 0.05$)
W = whole sample
X = CC beer drinkers
Y = BC beer drinkers
Z = Indiscriminate drinkers

The two methods of analysis therefore only showed significant variations in 10% of the comparisons for odour and 10.5% of the comparisons for taste. It was assumed that this slight variation between results from the two methods was due to the robustness of the ANOVA[123] allowing it to withstand the deviation from normality exhibited by, and indeed expected from, these data. The use of parametric methods was therefore considered justified in this instance and only such results

will be reported during the remainder of this thesis.

Table 35(b) Significant variations between parametric and non-parametric ANOVA of taste preference scores

Beers	Sample	Variation from Parametric ANOVA	Variation from Non-Parametric ANOVA
A_1 v C	X		*
A_1 v G	W		*
A_1 v G	X		*
A_1 v K	X		*
A_1 v K	Z	*	
A_2 v G	X		*
A_2 v K	X		*
C^2 v K	Z	*	
C v N	X		*
C v R	X		*
G v H	X		*
G v M	X		*
G v N	X		*
G v O	X		*
G v R	X		*
H v K	W		*
K v N	X		*
K v R	X		*
K v R	Z		*

Footnote to Table 35(b)

* indicates significant difference between beers ($p \leq 0.05$)
W = whole sample
X = CC beer drinkers
Y = BC beer drinkers
Z = Indiscriminate drinkers

Whilst the multiway contingency tables revealed that neither odour nor taste preference variations could be explained in terms of demographic or drinking habits data, ANOVA of the sample divided according to beer type regularly consumed showed variations in preference data considered worthy of further discussion.

The significant preference shown for the odour of BC beers by the entire sample was, after sub-division of the sample, only shown by the sub-sample of regular BC drinkers. This is not surprising as it would be expected that regular drinkers of one beer type would show a significant preference for the odour of that particular type of beer. The lack of significant preference for the odour of either beer type by indiscriminate drinkers can also be readily explained by the lack of regular consumption

of one particular beer type. Indiscriminate drinkers also showed no significant preference between the odours of the six most preferred beers (C, A_1, K, R, G and A_2 , see Table 31(c), page 97). However, since only one of these beers was a CC beer, this suggested a degree of preference for the odour of BC beers for this sub-sample too. Although regular drinkers of CC beers did not show a significant preference for the odour of CC beers, results in Table 31(a), page 97 show that two of the five beers which possessed the highest preference ratings (and between which there was no significant preference) were CC beers. This suggests a relatively greater preference for the odour of CC beers as would be expected from regular drinkers of this beer type. However, this preference appears to be only for individual CC beers and not for the beer as a type; CC beer drinkers would therefore discriminate in terms of odour preference against the CC beer they dislike as much as against BC beers.

In the case of taste, there was a very significant preference for BC beers, both by the whole sample and by all sub-samples. Once again, as for odour preference, the preference for BC beers, both as a type and as individual beers, was strongest in the case of BC beer drinkers, as might be expected. CC beer drinkers showed no significant preference between individual beers but a comparison of the relative order of preference for odour Table 31(a), p. 97) and for taste (Table 32(a), p. 98) clearly shows a decrease in the order of preference for certain CC beers, particularly beers N and R. It would appear therefore that whilst the odour of these CC beers was preferred to that of a number of BC beers, this relative preference did not apply when the beers were compared for taste. It was this decrease in the relative preference for beers N and R which resulted in a clearer discrimination between the taste of beer types by CC beer drinkers. This decrease in the relative preference for the taste of beers N and R was also shown by the other sub-samples. Although indiscriminant beer drinkers showed a significant preference for the taste of BC beers, there was a considerable overlap for preference of individual beers of both types, probably due to the lack of regular consumption of one particular beer type.

Closer examination of the data in Tables 28, 31, 32, pages 92 , 97 and 98 respectively, suggested that a classification of beers might be possible using the variation in odour and taste preference between individual beers. To inter-compare these variations in preferences, matrices were constructed for odour (Fig. 13(a)) and for taste (Fig. 13(b)).

Fig. 13(a) A matrix showing variation in preferences for the odour of beers

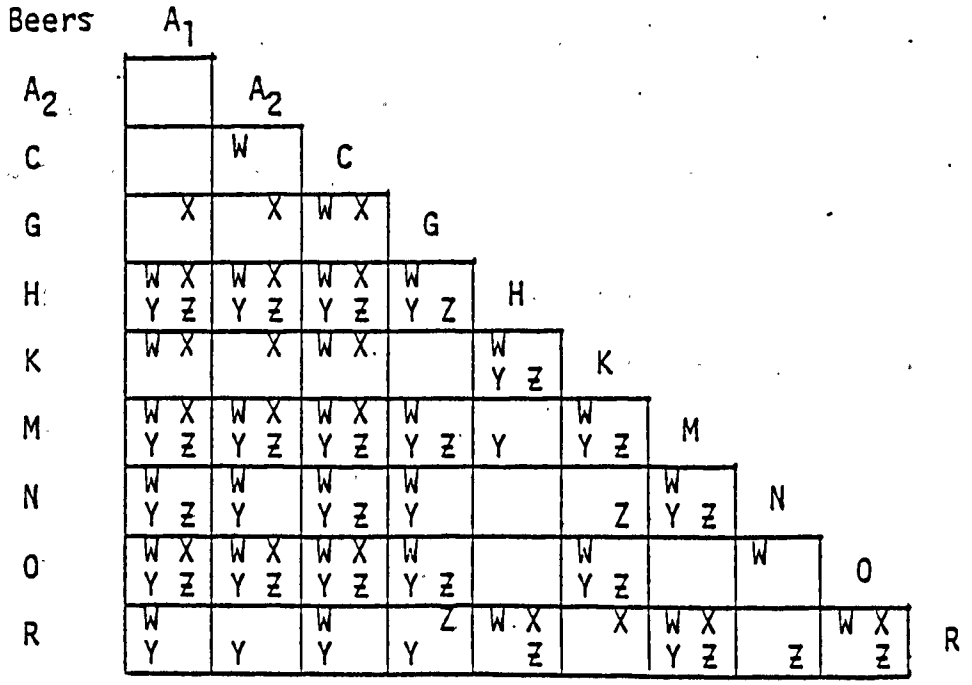
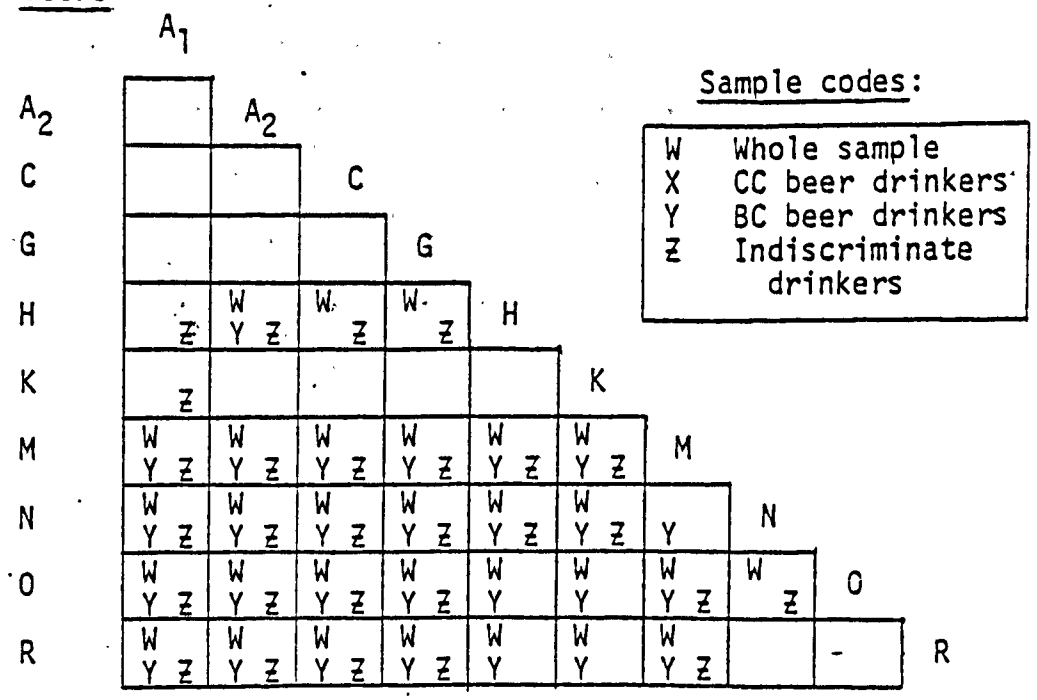


Fig. 13(b) A matrix showing variation in preferences for the taste of beers

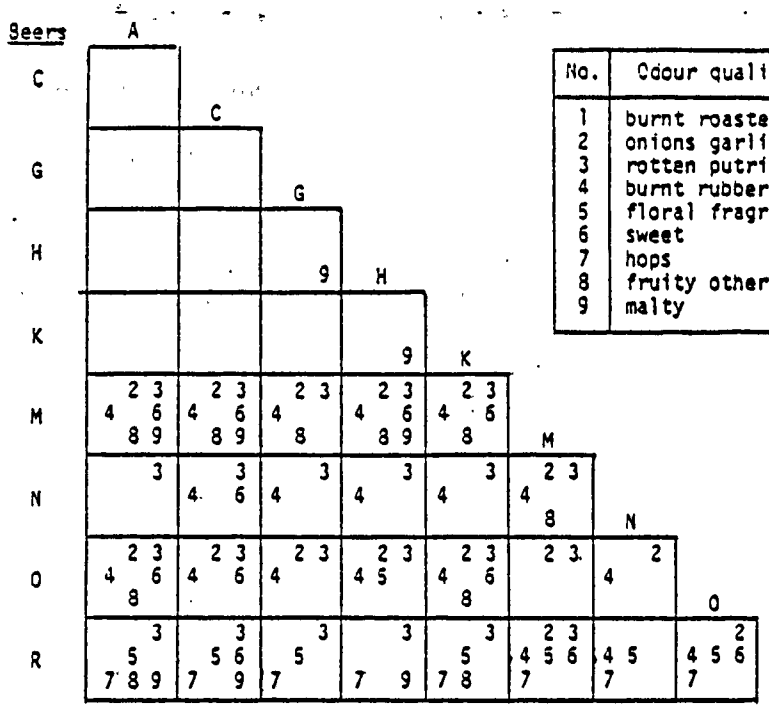


Footnote to Fig. 13. A letter in any given cell signifies significant preferences ($p \leq 0.05$) by the sample or sub-sample for each particular pair of beers.

By inspection of horizontal and vertical lines in the matrices, each pair of beers may be compared. Fig. 13(a) shows that relatively few of the sub-samples indicated a significant preference for the odour of BC beers A_1, A_2, C and G when paired combinations of any of these are inter-compared. Conversely a majority of the sub-samples indicated a significant preference for one beer when members of the group H, M and O were compared with either A_1, A_2, C or G. This could suggest a certain homogeneity or similarity (reflected in preference characteristics) within the group of beers A_1, A_2, C or G on the one hand and the group H, M and O on the other hand. In the case of taste (Fig. 13(b)), BC beer K can be added to the group of BC beers showing this high level of homogeneity, i.e. A_1, A_2, C, G, K. The similarity between BC beer H and CC beers M and O is not shown for taste however.

An interesting comparison can now be made between these subjective preference variations and the more objective data obtained from the trained assessors (see page 35). A matrix constructed using the odour qualities in which the beers differed significantly ($p \leq 0.05$) as shown by the trained assessors (Figure 14(a), page 108) shows a similar pattern emerging, and an even clearer division between beer types is shown. The lack of significant variation in preference (consumer data) between three of the five BC beers, A_1, A_2, C and G, does correspond with the lack of significant difference (trained panel data) in the odour qualities of these beers. Similarly the significant variation between beers M and O and beers A, C and G is also shown in Fig. 14(a), page 108 , although the variation in preferences for the odour of beer H is not reflected in the odour qualities of this beer. When taste preferences (Fig. 13(b)) were compared with taste differences, as shown by the trained panel (Fig. 14(b)), similar agreement was found. In this instance however the division

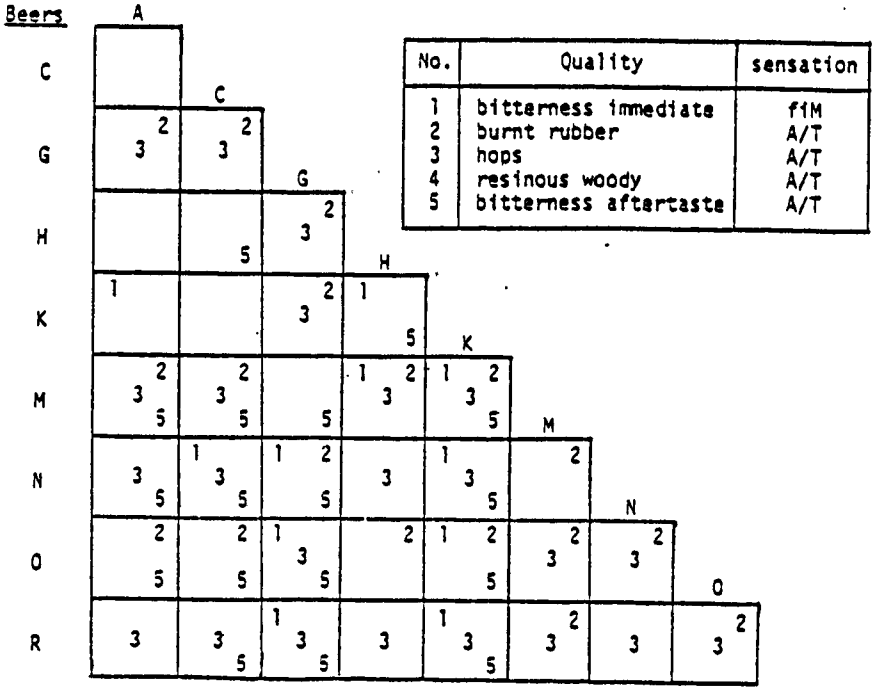
Fig. 14(a) Matrix of odour qualities in which beers differed significantly ($p \leq 0.05$)



No.	Odour quality
1	burnt roasted
2	onions garlic
3	rotten putrid
4	burnt rubber
5	floral fragrant
6	sweet
7	hops
8	fruity other
9	malty

Footnote to Fig. 14(a) Numbers in each cell refer to the odour qualities for which the two beers compared differed significantly ($p \leq 0.05$)

Fig. 14(b) Matrix of taste qualities in which beers differed significantly ($p \leq 0.05$)



No.	Quality	sensation
1	bitterness immediate	f1M
2	burnt rubber	A/T
3	hops	A/T
4	resinous woody	A/T
5	bitterness aftertaste	A/T

Footnote to Fig. 14(b) Numbers in each cell refer to the flavour-in-mouth and aftertaste qualities for which the two beers compared differed significantly ($p \leq 0.05$)

between beer types and the homogeneity of the BC beers A_1, A_2, C, G and K was clearer in the preference data (Fig. 13(b)).

These results suggest some relationship between the variation in preferences for the selected beers (consumer survey) and significant differences between the flavour qualities of these beers (laboratory panel). In order to investigate the existence of such a relationship, the consumers' reasons for the variations in preferences were determined, and it was this investigation which formed the basis of the remainder of this research.

C. (ii) Descriptive reasons for stated odour preferences (Question 13(b), page 83) and for (vi) stated taste preferences (Question 16(b), page 84).

A total of 2354 different odour descriptions and 3142 different taste descriptions was obtained from the consumers as reasons for their preference for the odour and taste respectively of the selected beers. In order to group these in some meaningful way (to facilitate interpretation) use was made of the "International System of Beer Flavour Terminology" published in 1976 by Clapperton, et al..[60] Using the tier structure of this system (described on page 13), the odour descriptions obtained from the consumers were categorised into an appropriate class of the International System (Table 36(a), p. 111).

An identical classification of the consumers' taste descriptions was performed as shown in Table 36(b),p.112. For the last two classes in Table 36 certain sub-divisions were introduced, by us, in order to group appropriately terms of related meanings obtained from the consumers. Thus, sub-classifications of 'high' and 'low' were necessary for 'carbonation' (Class 39), while the term 'body' (Class 40) required six sub-divisions, i.e.

A. terms relating to watery odour/taste
B. terms relating to fullness of odour/taste
C. terms relating to a lack of odour/taste character
D. terms relating to an odour/taste with body
E. terms relating to an odour/taste with a lack of body
F. terms relating to a non-watery odour/taste

In this way, as high a figure as 76% (1791) of the consumers' odour descriptions and 77% (2434) of their taste descriptions were condensed into the 40 classes of the International System. The remaining terms were considered too subjective to be incorporated into this relatively objective system. However they appeared to fall into seven additional categories, i.e.

Class 41. terms involving beer-like descriptions

Table 36(a) Classification of odour descriptions, obtained from consumers in this project, into the International System of Beer Flavour Terminology.[60]

INTERNATIONAL SYSTEM Class No	Odour Class	Classification of odour descriptions, obtained from consumers in this project, into the International System of Beer Flavour Terminology. *
1	Spicy	
2	Alcoholic	Alcoholic(48), Alcohol(10), Wine-like(12), Spirit-like(1), Rum(1), Gin(1), Fermenting(1)
3	Solvent-like	Chemical(9), Ether(2), Acetone(1), Plastics(1), Polish(1), Paint stripper(1), Paint brush cleaner(1), Floor cleaner(1).
4	Estery	Peardrops(1), Glue-like(1)
5	Fruity	Fruity(37), Shandy(2), Orange cordial(1), Lemonade(1), Citric Acid(1), Apple(6), Apple Juice(1), Banana(3), Blackcurrants(3), Cherries(1), Pear(1), Raspberry(1), Strawberry(3), Pomegranite(1)
6	Floral	Floral/flowers(11), Perfumed(11), Fragrant(3), Scented(6), Rose-like(2), Candyfloss(2)
7	Acetaldehyde	Cider(9), Rotten Apples(2)
8	Nutty	Nutty(17), Peanuts(18)
9	Resinous	Woody(12), Musky(1)
10	Hoppy	Hoppy(110)
11	Grassy	Leafy(1), Green(1), Damp grass(1), Stinging nettles(1), Herbs(2), Country smell(1), Country pub(1)
12	Straw-like	Dead leaves(1)
13	Grainy	Mealy(1)
14	Malty	Malty(64), Malt liquor(1)
15	Worty	
16	Caramel	Caramel(5), Burnt sugar(3), Toffee(1), Toffee apples(3), Mint toffee(1), Syrupy(1), Sugary(3), Treacle(1)
17	Burnt	Burnt(5), Burnt coffee(1), Dry(3), Acrid(4), Drinking chocolate(1), Smoky(2), Ashtrays(2) Cigarettes(1) Burnt toast(2), Roasted(4), Cooked(1), Processed(1), Pasteurised(1), Aniseed(1), Fireplace(1), Puffed wheat(1)
18	Medicinal	Medicinal(6), Clinical(1), Bleach(1), Harpic(1), Disinfectant(1). Hospital like(2), Cough drops(1), Antiseptic(2), Tablets(1), Pub loo(1) Tarry(2)
19	Diacetyl	Butter-warm(1), Creamy(1)
20	Fatty Acid	Soapy(5), Washing-up liquid(2), Dishwater(1), Sour cheese(2), Cheesy(1), Yoghurt(1) Sweaty socks(1), Fairy liquid(1), Beer shampoo(1), Washing-up water(2), Dishcloth(1), Cheesy-oad(1)
21	Oily	Greasy(1), Margarine(1), Petrol(1), Waxy(1)
22	Rancid	Rancid(1), Rancid milk(1), curdled(1)
23	Fishy	Ammonia(1), Seaweed(1)
24	Sulphitic	Made him cough(2)
25	Sulphidic	Sulphury(2), H_2S(2), Rotten/bad eggs(7), Rotten vegetables(1), Rotten cabbage(1) Drains(1) Stagnant ponds(2), Stink bombs(3), Rotten(6), Putrid(2), Rubber(3), Old tyres(1), Burning rubber(3), Manure(1) Sewage(4), Dirty water(1), Council flats(1)
26	Cooked vegetables	Vegetables cooking(2)
27	Yeasty	Yeasty(30), Pigs liver(1)
28	Ribes	
29	Papery	Off(61), Wet tea towel(1), Stale(23), Dirty beer glass(1), Not fresh(1), Taint(1)
30	Leathery	
31	Mouldy	Mouldy(2), Earthy(3), Musty(5), Mucky fields(1)
32	Sweet	Sweet(184), Sickly(25), Sickening(4), Honey(3)
33	Salty	Salty(1)
34	Acidic	Acidic(7), Sour(31), Sharp(14), Vinegar(25), Pungent(10)
35	Bitter	Bitter(67), Quinine(1)
36	Metallic	Metallic(4), Tinny(4), Canned beer(3)
37	Astringent	Astringent (2)
38	Powdery	Rough(1)
39	Carbonation: A High	Gassy(11), Fizzy(4), Tangy(22), Kick to it(1)
	Carbonation: B Low	No life(3), Not gassy(1), Not fizzy(1), Flat(36), Still(2)
40 Body	A Watery	Watery(11), Flavoured water(1), Thin(2)
	B Fullness	Strong(85), Potent(2), Too potent(6), Lots of smell(9), Too much smell(1), Odourful(6), Aromaful(1), Flavourful(4), Flavoursome(2)
	C Lack of Character	Weak(78), Faint(14), Slight(8), Little smell(38), Odourless/no smell(99), Not distinctive(4), Neutral(10), Not much smell(91), Not very odourful(1), Not too/very much(34), Not strong enough(4), Innocuous(1), Dull(1), Bland(10), Insipid(11), Dead(1), Moderate(1), Mundane(1), Intermediate(1), Indifferent(2), Uninspiring(2), No impression(1), Non-descript(1), Not like anything(4), Not a lot(2), Nothing much(7), Nothing particular(7), Wishy washy(1), Not too/very distinct(18), No character (12), Slight character(2) Not strong smell(4) Hardly any smell(5).
	D Body	Full(1), Body(10), Full-bodied(3), Bite(1), Heavy(22).
	E Lack of body	No body(1), Not much body(1), Little body(1), Weak bodied(1)
	F Not Watery	

* figures in brackets represent the frequency of use of each term.

Table 36(b) Classification of taste descriptions, obtained from consumers in this project, into the International System of Beer Flavour Terminology.[60]

INTERNATIONAL SYSTEM			Classification of taste descriptions, obtained from consumers in this project into the International System of Beer Flavour Terminology. *
Class No.	Taste Class		
1	Spicy		Spicy(3), Peppery(1)
2	Alcoholic		Alcoholic(32), Wine-like(8), Babycham(1), Spirit-like(1), Rum(1), Gin(1), Whisky(2), Advocat(1).
3	Solvent-like		Chemical(10), Ether(1)
4	Estery		Pear drops(3), Glue-like(1)
5	Fruity		Fruity(107), Citrus (1), Orange cordial(1), Lemonade(3), Banana(2), Pear(1), sloes(1)
6	Floral		Floral/flowers(39), Perfumed(10), Fragrant(2), Scented(9), Cosmetics(1)
7	Acetaldehyde		Cider(5), Rotten apples(1)
8	Nutty		Nutty(15), Hazelnuts(1), Almonds(1)
9	Resinous		Woody(7)
10	Hoppy		Hoppy(52)
11	Grassy		Grass(1), Stinging nettles(1), Country(1), Rustic(1), Water-cress(1)
12	Straw-like		
13	Grainy		
14	Malty		Malty(118)
15	Worty		
16	Caramel		Caramel(25), Burnt sugar(11), Toffee(10), Syrupy(1), Sugary(1)
17	Burnt		Burnt(44), Burnt toast(29), Burnt wood(4), Acrid(2), Roasted(4), Processed(3), Pasteurised(1), Cigarette ash(1)
18	Medicinal		Medicinal(3), Clinical(1), Hospital-like(1), Injections(1), Tablets(1)
19	Diacetyl		Creamy(3)
20	Fatty acid		Soapy(9), Washing-up liquid(1), Detergent(1), Soda(4), Washing-up-water(1), Dishwater(6), Cheesy(2)
21	Oily		Oily(2)
22	Rancid		Rancid(3)
23	Fishy		Seaweed(1)
24	Sulonitic		
25	Sulphidic		Sulphury(2), Rotten eggs(3), Rotten(33), Putrid(1), Burning rubber(1), Sewage(2), Stagnant ponds(1), Rubbish(2), Muddy water(1)
26	Cooked vegetables		Cauliflowers(1), Cabbage-like(1)
27	Yeasty		Yeasty(9)
28	Ribes		
29	Papery		Oxidised(2), Old beer(5), In bottle too long(1), Off(32), Stale(12), Dirty(1)
30	Leathery		
31	Mouldy		Mouldy(2), Earthy(1), Musty(1), Fungus(1), Gardens(2)
32	Sweet		Sweet(202), Sickly(13), Honey(1)
33	Salty		Salty(1)
34	Acidic		Acidic(12), Sour(138), Sharp(105), Vinegar(13), Pungent(1)
35	Bitter		Bitter(184)
36	Metallic		Metallic(4), Tinny(1), Canned beer(3), Iron(1)
37	Astringent		Dry(35), Mouthdrying(5), Astringent(3)
38	Powdery		Rough(4), Coarse(1), Harsh(2)
39	Carbonation	A High	Gassy(83), Fizzy(78), Tangy(29), Strong tang(3), Bubbly(2), Frothy(2), Bouyant(1), CO_2(1), Tingling(1), Pressurised(1), Lively(10), Not flat(4), Kick to it(4)
		B Low	No gas(1), No head(1), No life/lifeless(8), Not enough gas(1), Not gassy(7), Not too gassy(7), Not fizzy(13), Not too fizzy(3), Flat(101), Still(2), No kick(2)
40	Body	A Watery	Watery(103), Thin(16)
		B Fullness	Strong(54), Potent(2), Overpowering(8), Lots of taste/flavour(2), Too much taste/flavour(2), Flavourful(16), Higher level of taste(1), Flavoursome(1)
		C Lack of character	Weak(56), Slight(3), Little taste/flavour(15), Tasteless/flavourless/no taste/no flavour(48), Not enough flavour(1), Not distinctive(2), Not much taste/flavour(30), Hardly any taste/flavour(2), Not too/very much(24), Not strong taste/flavour(8), Not strong enough(2), No power(1), Low alcohol(1), No real punch(1), No character(7), Dull(4), Bland(10), Plain(1), Wet(1), Insipid(11), Dead(3), Medium(1), Moderate(1), Neutral(3), Indifferent(2), Ordinary(1), Regular(1) Negative(1), No marked impression(1), Does not stimulate(2), Non-descript(9), Featureless(3), Not too/very distinct(11), Not too much(8), Nothing(3), Nothing special(6), No extremes(1), Wishy washy(3), Normal(1)
		D Body	Full(2), Body(24), Full-bodied(9), Bite(8), Heavy(8), Not dull(1), Build up of flavour(1)
		E Lack of body	No body(9), Not much body(2), Not enough body(2), Little body(2), Lacks body(5), Not full bodied(1), Not full(1), Weak bodied(5)
		F Not watery	Not thin/watery(4), Not watered down(1), Thick(4), Viscous(1)

* Figures in brackets represent the frequency of use of each term.

Table 37(a) Classification of odour descriptions, obtained from consumers in this project, which could not be integrated into the International System of Beer Flavour Terminology.[60]

Class No.	Odour Class		Classification of odour descriptions, obtained from consumers in this project, which could not be included in the International System of Beer Flavour Terminology *
41	Beer-like descriptions		Beer smell(1), Beery(16), Normal beer(2), Like bitter(2), Homemade beer(16), Overdone homebrew(1), Beer out of wood(1), Beer from barrel(5), Bottom of barrel(7), Old fashioned beer(1), Ale(5), Strong ale(1), Pub(7), Old pubs(1), Brewery(2), Kitchen after party(1), Beer cellar(2), Last one out of barrel(3)
42	Specific beer Terms	A Beer types	Keg beer(2), Draught beer(2), Bottled beer(7), Spanish beer(1), Real ale(5), Lager like(9), Light ale(17), Mild(6), Light and bitter(3), Pale ale(4), Brown ale(13), Dark beer(1), Export beer(1), Barley wine(7), Stout(2)
		B Beer brands	Bass(2), Ben Truman(3), Brakspears(1), Burton ales(1), Charles Wells(1) Charringtons(6), Courage(2), Crown(1), Double Diamond(3), Fullers(3) Ind Coope(1), King & Barnes(1), Newcastle Brown(4), Safeways(1), Watneys(8), Shepherd Name(1), Worthington(1), Youngs special(4), Youngs(4)
43	Hedonic Terms	A Pleasant	Pleasant(50), Drinkable(2), Palatable(1), Appealing(4), Aphrodisiac(1), Heavenly(2), Fresh(6), Refreshing(1), Thirsty feeling(3), Wholesome(2), Nice(10), Good beer(14), Reasonable(1), Smells good(10)
		B Unpleasant	Do not like smell(2), Does not give appetite(1), Does not smell interesting(1), Not good(1), Not pleasant(10), Awful(3), Horrible(8), Bad(10), Terrible(1), Foul(5), Offensive(2), Obnoxious(2), Revolting(4), Repugnant(1), Cheap and nasty(1), Nauseating(2)
44	Meaningless negative terms		Not beer(15), Not like beer(5), Not fruity(3), Not sweet(4), Not yeasty(1) Not vinegary(2), Not matly(6), Not so aromatic(1), Not too bitter(1), Not too sour(2), Not too malty(1), Not too heavy(3), Not too heady(1), Not very chemical(1), Not hoppy enough(6), Not too acid(4), Not too sweet(6) Not very rich(3), Not fruity enough(4)
45	General meaningless terms		Blurred(1),Boring(1), Common(1), Familiar(5), Cheap(3), Subtle(3), Realistic(1), Solid(1), Hard(1), Twang(6), Homely(1),Natural(9), Healthy(1) Synthetic(2), Artificial(2), Commercial(1), Classier(1), Odd(1),Strange(4), Funny(2), Worse(1), Something wrong(3), Something added(2), Poor quality(1) Out of condition(1), Moderate(1), Couldn't drink more than one glass(1)
46	Subjective terms		Clean(2), Clear(3), Doesn't last long(2), Smooth(5), Mellow(8), Rich(8), Mature(1), Immature(7), Balanced(1), Well matured(1), Over-ripe(1), Not fermented(1), Incomplete manufacture(1), Well balanced(1), Mediocre(2), Just right(2), Positive(3)
47	Miscellaneous terms		Coca-cola(1), Aromatic(8), Soda water(1), Biscuits(1), Stale biscuits(1), Slops, cold tea(2), Urine(3), Coffee(1), Chewing gum(1), Minty(2), Senapods(1), Soft drink(2), Original(1)

* figures in brackets represent the frequency of use of each term.

Table 37(b) Classification of taste descriptions, obtained from consumers in this project, which could not be integrated into the International System of Beer Flavour Terminology.[60]

Class No.	Taste Class		Classification of taste descriptions, obtained from consumers in this project, which could not be included in the International System of Beer Flavour Terminology. *
41	Beer-like descriptions		Beery(3), Ordinary beer(1), Normal beer(1), Proper beer(1), Definite beer taste(1), Best Bitter(2), Like bitter(1), Slimming beer(1) Average bitter(2), Home made beer(10), Beer from wood(5), Bottom of barrel(4), Dregs(1), Old fashioned beer(3), Dirty oub(1)
42	Specific beer terms	A Beer types	Keg beer(14), Draught beer(1), Bottled beer(10), Real ale(2),lager like(5), Light ale/beer(20), Light and bitter(4), Pale ale(3), Mild(12), Brown ale(6), Barley wine(2), Stout(2)
		B Beer brands	Brakespears(1), Charringtons(2), Courage(1), Double Diamond(3), Fullers(2), Gales(1), Ind Coope(1), King and Barnes(1), Newcastle brown(1), Watneys(2), Whitbread tankard(1), Whitbread trophy(2), Worthington(1), Youngs Special(5), Guiness(1)
43	Hedonic terms	A Pleasant	Pleasant(69), Drinkable(6), Palatable(4), Heavenly(3), Tastes OK(2), Fresh(6), Refreshing(9), Satisfying(4), Mouthwatering(3), Thirst Quenching (6), Wholesome(1), Nice(8), Not Bad/Nasty(13), Good(4), Goes down easily(2), Grows on you(3) Gets better as you drink it(1), Inoffensive(9), Tasty(2)
		B Unpleasant	Uninteresting(3), Not good(2), Unpleasant(14), Awful(2), Horrible(6), Disgusting(1), Terrible(2), Bad(7), Foul(6), Nasty(4), Offensive(2), Revolting(3), Repulsive(2), Unpalatable(1), Nauseating(3), Couldn't drink much(2), Not enthusiastic(3)
44	Meaningless negative terms		Not beer(1), Not like beer(6), Not fruity(1), Not sweet(9), Not bitter(12), Not sour(1), Not malty(4), Not so aromatic(2), Not too bitter(19), Not too sour(9), Not hard on palate(4), Not too acid(4), Not too hoppy(1), Not too burnt(2), Not too sweet(18), Not too pungent(1), Not too dry(1), Not too light(1), Not very rich(1), Not fruity enough(1), Not flowery enough(1), Not malty enough(2), Doesn't taste like beer(7), Not very bitter(7)
45	General meaningless terms		Mineral(2), Familiar(2), Subtle(2), Synthetic(2), Artificial(1), False(1), Blunt(2), Last year's holiday(1), Strange(1), Chewy(1), More(1), Anaemic(2), Odd(3), Funny(1), Something added(2), Poor quality(2), Not quite right(1), Peculiar(2), Below par(1), Not natural(2), Out of condition(2), Natural(2)
46	Subjective terms		Clean(9), Instantaneous(2), Not slimy(1), Doesn't last long(1), Doesn't linger(2), Wastes away(1), Changes in mouth(2), Stays in mouth(1), Lingering(8), Long-lasting(2), Mouth clinging(6), Mouth coating(2), Smooth(96), Mellow(2), Rich(7), Slimy(2), Swallowing a raw egg(1), Mature(4) Immature(2), Well-matured(2), Not properly fermented(1), Balanced(4), Well balanced(1)
47	Miscellaneous terms		Coca-cola(1), Aromatic(4), Soda water(1), Biscuits(1), Stale biscuits(1), Urine(1), Brighton rock(1), Minty(2), Syrup of figs(1), Dandelion(1), Health Drink (1), Soft drink(2), Unique(3), Original(3), Unusual(9), Distinctive(4)

* figures in brackets represent the frequency of use of each term.

Class 42. terms involving specific beer terms related to beer types or brands

Class 43. hedonic terms

Class 44. meaningless negative terms

Class 45. general meaningless terms

Class 46. terms with a definite subjective meaning

Class 47. miscellaneous terms which do not bear sufficient similarity to existing terms in each class or are not sufficiently specific for classification

Table 37 (a) and (b) p. 113, 114 present these additional subjective categories and the appropriate terms as obtained from the consumers. These subjective classes were not analysed further.

The doubt, held by many, of the ability of consumers to describe and communicate perceived sensations and thereby give adequate and meaningful reasons related to the sensory properties of the product for any stated preference, has already been discussed (see Introduction). It was extremely encouraging therefore to find that 76% of the odour and 77% of the taste descriptions given by the consumers could be classified into the objective "International System of Beer Flavour Terminology".[60] This shows that meaningful information of a descriptive nature can be obtained from consumers as long as the experimenter adequately separates out subjective and obviously meaningless terms.

The frequency of use of the classified odour and taste descriptions for each beer.

These are shown in Table 38(a) and (b), pages 116, 117. For any single beer, only those classes obtained from at least 5% of the consumers were further examined. The eleven classes for which at least one beer exceeded this minimum use level for odour and the sixteen classes for taste are marked in Tables 38(a) and (b) with asterisks.

These data were analysed in two ways:

(a) correlation of frequency of use with results obtained from the trained panel

Table 38(a) Frequency of use of classified odour descriptions for each beer

Class Number	Odour Quality	Beer	A_1	A_2	C	G	H	K	M	N	O	R
1	Spicy											
2	*Alconolic		6	4	8	7	7	4	6	8	9	15
3	Solvent-like		1	3		2		3	1	2	2	3
4	Estery		1									1
5	*Fruity		2	2	6	9	5	12	9	6	1	10
6	Floral		2	1	1	7	1	5	2	4	4	8
7	Acetaldenyde			2	3		1		1	1	1	2
8	Nutty		1	2	2	1	2	1	1	2	6	
9	Resinous		1	2		3	1	2	2		1	1
10	*Hoppy		12	9	16	10	5	5	20	9	11	13
11	Grassy			1	1		1		2	1	1	1
12	Straw-like				1							
13	Grainy			1								
14	*Malty		7	8	7	6	12	6	4	6	9	2
15	Worty											
16	*Caramel		1	1			11	2		1	1	1
17	Burnt		1	2	2	4	2	3	7	2	5	2
18	Medicinal			2	1	2	1	4	4	1	2	2
19	Diacetyl						1	1				
20	Fatty Acid			3	1		2	2	3	3	2	3
21	Oily					1	2					1
22	Rancid						2				1	
23	Fishy							1				1
24	Sulphitic		1	1								
25	*Sulphidic		1		1	2	4		25	4	4	1
26	Cooked Vegetables								1		1	
27	Yeasty			2	3	2	5	2	8	5	3	1
28	Ribes											
29	*Papery		5	2	3	6	16	3	29	4	13	7
30	Leathery											
31	Mouldy			2			1		2	1	2	3
32	*Sweet		13	24	11	23	38	37	10	19	15	26
33	Salty							1				
34	*Acidic		4	8	10	9	14	5	11	5	12	9
35	Bitter		2	6	7	7	2	4	10	9	9	12
36	Metallic		1	1	1	1	2	1	1	3		
37	Astringent		1									1
38	Powdery							1				
39a	Carbonation-High		7	5	4	4	1	4	2	5	1	5
39b	Carbonation-Low		2	2	2	4	1		3	10	10	9
40a	Body-watery			1		2	2		2	2	4	1
40b	*Body-fullness		12	9	7	8	11	13	23	5	10	18
40c	*Body-lack of character		70	61	55	52	30	53	8	56	49	42
40d	Body-body		6	2	3		2	3	2	2	1	1
40e	Body-lack of body		1					1			2	
40f	Body-not watery											
41	Beer-like descriptions		10	10	12	4	1	6	6	13	5	7
42a	Specific beer-types		10	11	14	4	14	4	4	5	8	6
42b	Specific beer-brands		8	5	2	8	2	3	5	5	1	9
43a	Hedonic-pleasant		11	10	15	12	10	15	8	10	6	10
43b	Hedonic-unpleasant		4	2	3	2	7	1	25		7	3
44	Meaningless-negatives		3	6	14	5	4	7	4	9	6	6
45	General Meaningless		5	7	4	5	5	5	11	3	4	8
46	Subjective		4	8	4	3	6	5	4	4	7	4
47	Miscellaneous		3			2	3	6	5	1	4	1

Footnote to Table 38(a)

* Indicates odour classes obtained from at least 5% of consumers for at least one beer. BC beers are denoted in red and CC beers in green to aid identification.

Table 38(b) Frequency of use of classified taste descriptions for each beer

Class Number	Taste Quality	Beer	A_1	A_2	C	G	H	K	M	N	O	R
1	Spicy			1	1			1				1
2	Alcoholic		3	8	4	3	4	6	3	5	3	8
3	Solvent-like			1			2	2	1	1	1	3
4	Estery		1						1			2
5	*Fruity		8	15	4	19	10	20	5	6	9	20
6	*Floral		1	2	4	4	3	9	9	4	1	24
7	Acetaldenyde		1				1	2	1			1
8	Nutty			3	1				3		5	5
9	Resinous		1				1		3	2		
10	*Hoopy		6	4	5	4		3	13	5	6	6
11	Grassy			1					2		1	1
12	Straw-like											
13	Grainy											
14	*Malty		5	7	7	14	17	17	19	11	14	7
15	Worty											
16	*Caramel		3	5	2	3	15	9	1	1	8	
17	*Burnt		7	1	10	5	10	2	21	13	16	3
18	Medicinal			1			1	2		1		3
19	Diacetyl			1				1			1	
20	Fatty Acid		3	1	1	1	3		8	1	4	2
21	Oily						1		1			
22	Rancid		1					1			1	
23	Fishy									1		
24	Sulphitic											
25	*Sulphidic		1	1	2	1	3	3	20	8	3	4
26	Cooked Vegetables										1	1
27	Yeasty				1	1		1	3	1	1	1
28	Ribes											
29	*Papery		3	1	3	2	2	4	10	13	9	6
30	Leathery											
31	Mouldy							1	1	2	3	
32	*Sweet		15	26	17	26	32	44	7	9	13	22
33	Salty				1							
34	*Acidic		36	25	20	19	23	16	34	34	16	46
35	*Bitter		26	18	22	15	13	12	17	35	9	17
36	Metallic		1	2		3	2			1		
37	Astringent		3	4	7	2	2	3	4	7	3	8
38	Powdery			1	2				2		2	
39a	*Carbonation - High		45	61	31	35	17	17	3		4	6
39b	*Carbonation - Low		5	3	9	5	13	7	21	42	28	18
40a	*Body-watery		3	2	13	6	7	8	8	25	23	24
40b	*Body-fullness		12	14	9	7	9	10	9	4	5	7
40c	*Body-lack of character		38	22	40	25	28	28	12	29	45	21
40d	Body-body		7	7	7	8	8	5	9	3	5	4
40e	Body-lack of body		3	2	4	2	2	1	2	3	6	3
40f	Body-not watery			4	1	2	2	1				
41	Beer-like descriptions		5	9	1	3	1	2	10		3	3
42a	Specific beer-types		7	10	19	7	10	11	4	2	4	7
42b	Specific beer-orands		3	3		5	1	5	4	2	1	1
43a	Hedonic-pleasant		19	20	19	23	16	18	10	7	13	10
43b	Hedonic-unpleasant		2	3	5	4	5	5	19	3	6	7
44	Meaningless-negatives		14	10	21	9	15	9	7	10	12	8
45	General Meaningless		2	4	3	2	4	5	5	4	5	2
46	Subjective		18	17	21	17	14	25	13	11	10	13
47	Miscellaneous		4	3	3	2	5	5	3	3	2	6

Footnote to Table 38(b)

* Indicates taste classes obtained from at least 5% of consumers for at least one beer. BC beers are shown in red and CC beers in green to aid identification.

(b) distribution of odour or taste classes across the hedonic scale

(a) Correlation of frequency of use of odour and taste classes (consumer survey) with intensities of flavour qualities (assessed by trained panel).

Two points are worth noting at the outset. Firstly, the descriptions obtained from the consumers were explanations of the stated hedonic response and not a complete descriptive analysis of the beer odours/tastes. Secondly, the qualities analysed by the trained assessors included (a) odour (b) flavour-in-mouth and (c) aftertaste descriptions of the overall flavour complex. It was thought reasonable to assume that the more prominent flavour qualities (i.e. those with the highest intensities as determined by the trained panel) would cause the greatest impact on the consumers' hedonic response and would, therefore, be used more frequently as reasons for a stated preference. It is this assumption that led to the presently attempted correlation.

This comparison was achieved by determining the degree of correlation between (i) the frequency of use of descriptions from consumers as classified in Table 38(a) and (b) p.116,117, and (ii) the intensity of the odour, flavour-in-mouth, and aftertaste qualities in the same beers, as determined by the trained assessors. Because of differences inherent in the vocabulary used by the trained assessors and that of the International System[60] (N.B. the International System was not published when the laboratory panel analysis began), it was only possible to make direct correlations for seven odour qualities and fourteen "taste" qualities the correlation coefficients are shown in Table 39(a) and (b) p. 119,120.

Results of these analyses showed that the frequency of use of odour classes from the consumers' descriptions correlated significantly with five of the nine odour qualities in which the individual beers had been found to differ significantly by the trained assessors ($p \leq 0.05$). Similarly, frequency of use of taste classes from the consumers' descriptions

correlated significantly with two of the four aftertaste qualities in which the individual beers had been found to differ significantly by the trained assessors ($p \leq 0.05$). These findings were also encouraging and are indications of further agreement in descriptive analysis between a laboratory panel and a consumer panel.

Table 39(a) Correlation between frequency of use of odour classes (obtained from consumers) and odour quality intensities determined by trained assessors)

Odour classes from consumer survey	Equivalent odour qualities used by trained assessors	Correlation Coefficient ($\times 10^3$)	Significant Differences (See Footnote)
fruity	fruity citrus	+ 032	
fruity	fruity other	- 172	1
hops	hops	+ 325	1, 2
hops	floral fragrant	+ 362	1
hops	herbal	+ 537	
malty	malty	+ 903 *	1
caramel	caramel, toffee	+ 438	2
sulphidic	rotten, putrid	+ 971 *	1
sulphidic	onions, garlic	+ 971 *	1
sulphidic	burnt rubber	+ 828 *	1
sweet	sweet	+ 785 *	1
acidic	sour, acidic, sharp	+ 232	2

Footnote to Table 39(a)

* Correlation significant at $p \leq 0.05$ (i.e. correlation coefficient ($\times 10^3$) > $\pm$ 564)

1. Trained assessors showed that odour of individual beers differed significantly in this quality ($p \leq 0.05$).
2. Trained assessors showed that the beer types differed significantly in this quality ($p \leq 0.05$).

N.B. Frequency of use for all beers were used to calculate correlation coefficients, including frequencies of use which did not exceed the 5% minimum level previously mentioned.

The relationship between rotten putrid, onions garlic and burnt rubber odours, as used by the trained panel, has already been discussed (see page 58). There it was concluded that these qualities could be regarded as representative of a single 'sulphidic factor', and hence the correlations shown in Table 39 are considered justifiable. The use of descriptions categorised into the malty odour class (class 14) by at least 5% of consumers, were restricted to beer H; similarly only beer

Table 39(b) Correlation between frequency of use of taste classes (obtained from consumers) and flavour-in-mouth and aftertaste quality intensities (determined by trained assessors)

Taste classes from consumer survey	Equivalent taste qualities used by trained assessors	Correlation coefficient flavour-in-mouth ($x10^3$)	Correlation coefficient aftertaste ($x10^3$)	Significant differences (see footnote)
fruity	fruity citrus	+330	+009	
fruity	fruity other	+250	+079	
floral	floral fragrant	+287	+794 *	5,6
floral	hops	+828 *	+834 *	4, 6
floral	herbal	+504	+565 *	6
hops	herbal	-324	+820 *	6
hops	hops	+261	+533	4, 6
hops	floral fragrant	-011	+688 *	5,6
malty	malty	+327	+021	5
caramel	caramel toffee	+219	-188	5
burnt	burnt roasted	+486	+890 *	
sulphidic	rotten putrid	+934 *	+934 *	
sulphidic	onions garlic	not scored by trained assessors		
sulphidic	burnt rubber	+499	+906 *	4
sweet	sweet	+584 *	+271	5,6
acidic	sharp acidic sour	+586 *	+228	5
bitter	bitter	+343	+190	3,4,5,6
body watery	thin watery	-240	+160	
body fullness	smooth mellow full bodied	+336	+379	
high carbonation	CO_2 tingle	+228	-	5
low carbonation	CO_2 tingle	-645 *	-	5

Footnote to Table 39(b)

* Correlation significant at $p \leq 0.05$ (i.e. correlation coefficient ($x10^3$) $> \pm 564$).

3 Trained assessors showed flavour-in-mouth of individual beers differed significantly in this quality ($p \leq 0.05$).

4 Trained assessors showed aftertaste of individual beers differed significantly in this quality ($p \leq 0.05$)

5 Trained assessors showed flavour-in-mouth of beer types differed significantly in this quality ($p \leq 0.05$)

6 Trained assessors showed aftertaste of beer types differed significantly in this quality ($p \leq 0.05$)

N.B. Frequency of use for all beers were used to calculate correlation coefficients, including frequencies of use which did not exceed the 5% minimum level previously mentioned.

M showed the odour class sulphidic to be used above this level. This prominence of these qualities in these particular beers largely accounts for the high correlations for malty and sulphidic entries in Table 39(a), p.119. Conversely, in the case of sweetness odour, the reasons for hedonic responses were used by at least 5% of the sample for all beers (except beer M). Thus the high correlation in Table 39(a) for the sweet odour quality shows a more global, but nonetheless, selective use of this quality by the consumer. Although there is a lack of significant correlation in Table 39(a) for fruity (class 5), hops (class 10) and caramel (class 16), these qualities were prominent in certain individual beers (as determined by the trained panel), and it is noteworthy that this was also reflected in the relatively high frequency of use of the same odour classes, in the corresponding beers, by the consumer. Most noticeable of these were:-

fruity (odour class 5) in BC beer K

hops (odour class 10) in CC beer M

hops (odour class 10) in CC beer R

caramel (odour class 16) in BC beer H

acidic (odour class 34) in CC beer M

acidic (odour class 34) in CC beer O

Results from the analysis of the taste descriptions, (Table 39(b) p.120, suggest some confusion regarding the use of hop associated taste classes by the consumer. As far as floral taste (class 6) was concerned, this found better agreement with hops than any other flavour-in-mouth quality used by the trained panel. The significant correlation between low carbonation (consumer) and CO_2 tingle (trained assessors) and the non-significant correlation between high carbonation (consumer) and CO_2 tingle (trained assessors) suggests that low carbonation is more directly related to reasons for preference than high carbonation. The use of descriptions categorised in the sweet and acidic taste classes showed the same global

but selective use by the consumer as shown for the sweet odour class. As in the case of the sulphidic odour class, the use of descriptions categorised into the sulphidic taste class by at least 5% of consumers, were restricted to beer M. This selective use was largely accountable for the significant correlation for this quality as shown in Table 39(b). It can be seen that taste data from consumers were more closely related with aftertaste data from the trained panel (eight significant correlations) than with flavour-in-mouth data from the trained panel (five significant correlations). As has already been shown (page 35) the beers examined by the trained panel differed significantly in more aftertaste qualities than flavour-in-mouth qualities, the differences therefore being highlighted to a greater degree by the intensities of the qualities perceived as aftertaste. It is not surprising therefore that the more prominent qualities detected by the consumers, and used as reasons for preference, should correspond more closely to the intensities of these aftertaste qualities perceived by trained assessors. Although there is a lack of significant correlation in Table 39(b) for hops (class 10), malty (class 14), caramel (class 16) and bitterness (class 35) for the flavour-in-mouth category, these qualities were prominent in certain individual beers (as determined by the trained panel). As with odour classes, it is noteworthy that this was also reflected in the relatively high frequency of use of the corresponding taste class by the consumer. Most noticeable of these were:-

hops (taste class 10) in CC beer M

malty (taste class 14) in BC beer H

caramel (taste class 16) in BC beer H

bitterness (taste class 35) in CC beer N

In order to analyse beer types in a similar fashion, the frequency of use of odour classes and taste classes for the two beer types were calculated from the consumer data as an average of the frequency of use of each class for all individual beers within each beer type. (Table

40(a) and (b) below).

Table 40(a) Average use of odour classes for beer types

Class No.	Odour Class	Total frequency for all beers	Average frequency of use for BC beers (as % of consumers)	Average frequency of use for CC beers (as % of consumers)	Predominant beer type
2	alcoholic	74	2.9	4.6	CC
5	fruity	62	2.9	3.1	CC
10	hops	110	4.6	6.4	CC
14	malty	67	3.7	2.5	BC
16	caramel	18	1.2	0.4	BC
25	sulphidic	42	0.6	4.1	CC
29	papery	88	2.8	6.4	CC
32	sweet	216	11.7	8.5	BC
34	acidic	87	4.0	4.5	CC
40B	body fullness	116	4.8	6.8	CC
40C	lack of aroma character	476	25.8	18.7	BC

Table 40(b) Average use of taste classes for beer types

Class No.	Taste Class	Total frequency for all beers	Average frequency of use for BC beers (as % of consumers)	Average frequency of use for CC beers (as % of consumers)	Predominant beer type
5	fruity	116	6.1	4.8	BC
6	floral	61	1.9	4.6	CC
10	hoppy	52	1.8	3.6	CC
14	malty	118	5.4	6.2	CC
16	caramel	47	3.0	1.2	BC
17	burnt	88	2.8	6.4	CC
25	sulphidic	46	0.9	4.2	CC
29	papery	53	1.2	4.6	CC
32	sweet	216	12.9	6.8	BC
34	acidic	269	11.2	15.7	CC
35	bitter	184	8.5	9.4	CC
39A	carbonation - high	219	16.6	1.6	BC
39B	carbonation - low	151	3.4	13.2	CC
40A	body-watery	119	3.1	9.7	CC
40B	body-fullness	86	4.9	3.0	BC
40C	body-lack of taste character	288	14.6	12.9	BC

This showed that alcoholic, fruity, hops, sulphidic, papery, acidic and body fullness classes were used more often to explain hedonic response for the odour of CC beers, while malty, caramel, sweet and lack of odour character were used more often for BC beers. Yet again this result agrees extremely well with the earlier conclusions from the trained assessors, that malty, sweet and caramel odour characterised BC beers and that hops, acidic and sulphidic odours characterised CC beers. Thus the relative frequencies of use of odour classes indicates that the consumers, as shown in Table 40(a), confirm this distinction between beer types. In the case of taste, floral, hops, malty, burnt, sulphidic, papery, acidic, bitterness, low CO_2 and body watery classes were used more often to explain hedonic response to the taste of CC beers while fruity, caramel, sweet, high CO_2, body fullness and lack of taste character classes were used more often for BC beers. Once again this result agrees extremely well with conclusions from trained assessors that floral, hops, sulphidic, acidic, bitter and low CO_2 characterised CC beers and caramel, sweet and high CO_2 tastes characterised BC beers. The one exception was malty taste. This was due to the high level of use by consumers of this taste class for beer M, which was shown by the trained assessors to have a low intensity of this taste quality. This anomaly will be discussed later (page 132). The more frequent use of the odour class 'lack of odour character' and the taste class 'lack of taste character' for BC beers would tend to support the blandness theory discussed earlier (see p. 58).

(b) Distribution of odour/taste classes across the hedonic scale

In order to simplify the analysis, the hedonic scale was divided into 3 sections: ratings 1, 2 and 3 categorised as definite dislike ratings; 4, 5 and 6 as neutral ratings and 7, 8 and 9 as definite like ratings. Understandably, for any given odour (or taste) class and for any given beer, each section of the scale was used by a different number of consumers and therefore the percentage of consumers using each class

over each section of the scale was calculated for each beer. This percentage use was defined as follows: Percentage use of descriptions within odour (or taste) class X, for beer Y over section Z of the hedonic scale =

$$\frac{\text{frequency of use of description in odour (or taste) class X, over section Z, for beer Y} \times 100}{\text{number of consumers using section Z to rate beer Y}}$$

This was performed only for those beers for which an odour or taste class had been used by over 5% of the consumers (Table 41(a) and (b) p.126,127). In order to study the associations of odour or taste classes to the various sections of the hedonic scale, an 'hedonic index' was derived by converting the percentage of use into ratios. This was achieved by dividing the largest values by the smallest, these three values relating to the three sections of the hedonic scale. Hence sulphidic odour class for beer M with percentages of use of 20.4 (dislike scale), 6.7 (neutral scale) and 3.1 (like scale) had a hedonic index of:- $\frac{20.4}{3.1} : \frac{6.7}{3.1} : \frac{3.1}{3.1} = 6.6 : 2.2 : 1.0$

This indicates that descriptions categorised in this particular odour class were mainly used over the dislike part of the scale, i.e. sensory properties given as reasons for disliking beer M.

Table 41(a) shows that three odour classes were used on average to the greatest extent over the like section of the scale.

viz.: alcoholic
hops
body fullness

These are therefore desirable properties of beer odour.

Three odour classes were used on average to the greatest extent over the dislike scale.

viz.: sulphidic
papery
acidic

Table 41(a) Percentages of use of odour classes across the hedonic scale and calculated hedonic indices

Odour class	Beers for which class used by >5% of sample	% consumers scoring 1,2,3 i.e. dislike	% consumers scoring 4,5,6 i.e. neutral	% consumers scoring 7,8,9 i.e. like	hedonic index		
					dislike	neutral	like
alcoholic	R	6.8	4.2	11.9	1.6	1.0	2.8
fruity	K	4.4	5.1	7.8	1.0	1.2	1.8
hops	A_1	0	4.3	10.9	0	1.0	2.5
	C	0	5.9	11.2	0	1.0	1.9
	M	4.1	8.9	18.8	1.0	2.2	4.6
	O	0	4.0	20.6	0	1.0	5.2
	R	6.8	4.2	11.9	1.6	1.0	2.8
Average for all beers		2.2	5.5	14.7	1.0	2.5	6.7
malty	H	7.2	2.3	9.6	3.1	1.0	4.2
caramel	H	7.2	3.5	5.8	2.1	1.0	1.7
sulphidic	M	20.4	6.7	3.1	6.6	2.2	1.0
papery	H	15.9	5.8	0	2.7	1.0	0
	M	23.4	11.1	0	2.1	1.0	0
	O	15.3	2.0	0	7.7	1.0	0
Average for all beers		18.2	6.3	0	2.9	1.0	0
acidic	H	11.6	5.8	1.9	6.1	3.1	1.0
	M	7.1	6.7	1.6	4.4	4.2	1.0
	O	12.5	3.0	0	4.2	1.0	0
Average for all beers		10.4	5.2	1.2	8.7	4.3	1.0
sweet	A_1	3.8	7.7	4.7	1.0	2.0	1.2
	A_2	12.5	9.6	14.5	1.3	1.0	1.5
	C	0	6.9	4.5	0	1.5	1.0
	G	21.2	10.5	6.7	3.2	1.6	1.0
	H	20.3	19.8	13.5	1.5	1.5	1.0
	K	17.8	16.3	20.3	1.1	1.0	1.2
	N	8.0	10.6	6.8	1.2	1.6	1.0
	O	8.3	5.9	8.8	1.4	1.0	1.5
	R	9.1	15.6	10.4	1.0	1.7	1.1
Average for all beers		11.2	11.4	10.0	1.1	1.1	1.0
body fullness	A_1	7.7	2.6	10.9	3.0	1.0	4.2
	H	4.3	3.5	9.6	1.2	1.0	2.7
	K	6.7	4.1	9.4	1.6	1.0	2.3
	M	3.1	6.7	26.6	1.0	2.2	8.6
	R	11.4	7.3	8.9	1.6	1.0	1.2
Average for all beers		6.6	4.8	13.1	1.4	1.0	2.7
lack of odour character	A_1	38.5	46.2	9.4	4.1	4.9	1.0
	A_2	33.3	43.9	5.8	5.7	7.4	1.0
	C	43.8	39.2	9.0	4.9	4.4	1.0
	G	30.3	29.8	13.3	2.3	2.2	1.0
	H	10.1	24.4	3.8	2.7	6.4	1.0
	K	28.9	35.7	7.8	3.7	4.6	1.0
	N	20.0	38.1	6.8	2.9	5.6	1.0
	O	8.3	41.6	0	1.0	5.0	0
	R	20.5	32.3	3.0	6.8	10.8	1.0
Average for all beers		26.0	36.7	6.5	4.0	5.6	1.0

Table 41(b) Percentages of use of taste classes across the hedonic scale and calculated hedonic indices

taste class	Beers for which class used by >5% of sample	% consumers scoring 1,2,3 i.e. dislike	% consumers scoring 4,5,6 i.e. neutral	% consumers scoring 7,8,9 i.e. like	hedonic index: dislike	hedonic index: neutral	hedonic index: like
fruity	A_2	3.2	9.8	6.0	1.0	3.1	1.9
	G	3.7	10.0	10.0	1.0	2.7	2.7
	K	4.4	10.7	11.5	1.0	2.4	2.6
	R	6.6	12.7	11.3	1.0	1.9	1.7
average for all beers		4.5	10.8	9.7	1.0	2.4	2.2
floral	R	15.4	4.8	13.2	3.2	1.0	2.8
hoppy	M	6.1	5.4	7.3	1.1	1.0	1.4
malty	G	3.7	3.3	11.1	1.1	1.0	3.7
	H	8.5	4.8	14.3	1.8	1.0	3.0
	K	6.7	9.5	7.7	1.0	1.4	1.1
	M	1.7	10.8	23.6	1.0	6.4	13.9
	N	2.0	4.5	14.0	1.0	2.3	7.0
	O	4.1	6.4	10.9	1.0	1.6	2.7
average for all beers		4.5	6.7	13.6	1.0	1.5	3.0
caramel	H	8.5	7.7	5.4	1.6	1.4	1.0
burnt	M	13.0	10.8	3.6	3.6	3.0	1.0
	N	4.1	9.1	7.0	1.0	2.2	1.7
	O	10.8	6.4	5.5	2.0	1.2	1.0
average for all beers		9.3	8.8	5.4	1.7	1.6	1.0
sulphidic	M	15.7	0	3.6	4.4	0	1.0
papery	M	9.2	6.1	0	1.5	1.0	0
sweet	A_1	11.1	6.3	6.7	1.8	1.0	1.1
	A_2	19.4	15.2	7.1	2.7	2.1	1.0
	C^2	5.1	11.8	7.0	1.0	2.3	1.4
	G	11.1	14.4	11.1	1.0	1.3	1.0
	H	31.9	10.6	10.7	3.0	1.0	1.0
	K	22.2	21.4	20.5	1.1	1.0	1.0
	O	2.7	11.5	12.7	1.0	4.3	4.7
	R	13.2	9.5	7.5	1.8	1.3	1.0
average for all beers		14.6	12.6	10.4	1.4	1.2	1.0
acidic	A_1	30.6	11.5	18.7	2.7	1.0	1.6
	A_2	25.8	6.5	13.1	4.0	1.0	2.0
	C^2	20.5	11.8	4.0	5.1	3.0	1.0
	G	29.6	7.7	4.4	6.7	1.8	1.0
	H	12.8	15.4	1.8	7.1	8.6	1.0
	K	13.3	9.5	2.6	5.1	3.7	1.0
	M	20.0	18.9	7.3	2.7	2.6	1.0
	N	17.3	13.6	18.6	1.3	1.0	1.4
	O	9.5	5.1	19.1	1.9	1.0	3.7
	R	28.6	25.4	7.5	3.8	3.4	1.0
average for all beers		20.8	12.5	9.7	2.1	1.3	1.0

taste class	Beers for which class used by >5% of sample	% consumers scoring 1,2,3 i.e. dislike	% consumers scoring 4,5,6 i.e. neutral	% consumers scoring 7,8,9 i.e. like	hedonic index: dislike	hedonic index: neutral	hedonic index: like
bitter	A_1	8.3	12.5	14.7	1.0	1.5	1.8
	A_2	9.7	5.4	11.9	1.8	1.0	2.2
	C^2	5.1	11.8	12.0	1.0	2.3	2.4
	G	7.4	6.7	7.8	1.1	1.0	1.2
	H	4.3	3.8	12.5	1.1	1.0	3.3
	K	4.4	4.8	7.7	1.0	1.1	1.8
	M	7.0	10.8	9.1	1.0	1.5	1.3
	N	16.3	16.7	18.6	1.0	1.0	1.1
	R	5.5	6.3	15.1	1.0	1.1	2.7
average for all beers		7.6	8.8	12.2	1.0	1.2	1.6
high CO_2	A_1	33.3	26.0	10.7	3.1	2.4	1.0
	A_2	35.5	37.0	19.0	1.9	1.9	1.0
	C^2	28.2	16.2	9.0	3.1	1.8	1.0
	G	7.4	22.2	14.4	1.0	3.0	1.9
	H	8.5	8.7	7.1	1.2	1.2	1.0
	K	6.7	11.9	5.1	1.3	2.3	1.0
average for all beers		19.9	20.3	10.9	1.8	1.9	1.0
low CO_2	H	12.8	3.8	5.4	3.4	1.0	1.4
	M	10.4	2.7	14.5	3.9	1.0	5.4
	N	23.5	16.7	18.6	1.4	1.0	1.1
	O	17.6	15.4	5.5	3.2	2.8	1.0
	R	12.1	6.3	5.7	2.1	1.1	1.0
average for all beers		15.3	9.0	9.9	1.7	1.0	1.1
watery	C	5.1	10.3	4.0	1.3	2.6	1.0
	N	15.3	15.2	0	1.0	1.0	0
	O	18.9	10.3	1.8	10.5	5.7	1.0
	R	11.0	17.5	5.7	1.9	3.1	1.0
average for all beers		12.6	13.3	2.9	4.3	4.6	1.0
body fullness	A_1	2.8	3.1	10.7	1.0	1.1	3.8
	A_2	0	4.3	11.9	0	1.0	2.8
average for all beers		1.4	3.7	11.3	1.0	2.6	3.1
lack of taste character	A_1	22.2	26.0	6.7	3.3	3.9	1.0
	A_2	12.9	16.3	3.6	3.6	4.6	1.0
	C^2	30.8	26.5	10.0	3.1	2.7	1.0
	G	18.5	21.1	1.1	16.8	19.2	1.0
	H	14.9	15.4	3.9	1.7	1.7	1.0
	K	20.0	21.4	1.3	15.3	16.5	1.0
	M	7.0	10.8	0	1.0	1.5	0
	N	17.3	16.7	2.3	7.5	7.3	1.0
	O	24.3	30.8	5.5	4.4	5.6	1.0
	R	5.5	20.7	5.7	1.0	3.8	1.0
average for all beers		17.3	20.6	4.5	3.8	4.6	1.0

These are, therefore, undesirable properties of beer odour.

In the case of two odour classes, i.e. malty and caramel, the index was bimodal with high frequencies of use occurring at both the like and dislike ends of the scale. In the case of the odour classes sweet and lack of character, the index shows a concentration of use in the neutral and dislike zones, whereas fruity odour shows a bias towards the neutral and like zones.

From Table 41(a), the odour classes prominent in each beer were separated according to their individual hedonic indices; it was thus possible to conclude reasons in terms of odour properties for the hedonic responses for each beer. These are summarised in Table 42(a) (page 129). Reasons given for the conclusive hedonic response to beer M (whether like or dislike) can be seen in Table 42(a). Odour classes related to a definite favourable response to this beer were hops and body fullness, while, conversely, sulphidic, papery and acidic odours were associated with an unfavourable response. This result offers an explanation for the bimodality of the hedonic response to this beer (Table 27(a), page 91) whereby some form of selective recognition and acceptance of prominent odour qualities caused consumers to respond in opposing ways; those who liked the beer recognised the hops and body fullness qualities and accepted the beer, while those who disliked the beer recognised the sulphidic and papery odour and rejected the beer.

It was earlier shown that in common with CC beer M, two other beers (BC beer H and CC beer O) had low mean hedonic ratings for odour, both for the whole sample of consumers (Table 28(a), p. 92) and for the sub-divided sample (Table 31, p. 97). All three beers exhibited relatively high frequencies of use of the odour class papery, (see Table 38(a), page 116) which included such descriptions as old beer, stale beer and off-beer. The frequent use of this odour class for beers with low hedonic ratings is therefore not surprising.

CC beer R had the highest mean hedonic odour score of all the

Table 42(a) Proposed reasons for hedonic response to odour of individual beers based on hedonic indices

Beer	Beer type	Qualities used more in like zone i.e. reasons for liking	Qualities used more in neutral zone	Qualities used more in dislike zone i.e. reasons for disliking	Qualities showing bimodal distributions: like v dislike
A_1	BC	hops	sweet lack of character		body fullness
A_2	BC		lack of character		sweet
C	BC	hops	sweet lack of character		
G	BC		lack of character	sweet	
H	BC	body fullness	lack of character sweet	papery acidic	malty caramel
K	BC	fruity	lack of character		body fullness sweet
M	CC	hops body fullness	acidic	sulphidic papery	
N	CC		lack of character sweet		
O	CC	hops	lack of character	papery acid	sweet
R	CC	alcoholic hops	sweet lack of character		body fullness

Table 42(b) Proposed reasons for hedonic response to taste of individual beers based on hedonic indices

Beer	Beer Type	Qualities used more in like zone i.e. reasons for liking	Qualities used more in neutral zone	Qualities used more in dislike zone i.e. reasons for disliking	Qualities showing bimodal distributions: like v dislike
A_1	BC	bitter body fullness	lack of taste character	sweet acidic high CO_2	
A_2	BC	bitter body fullness	fruity lack of taste character high CO_2 sweet	acidic	
C	BC	[bitter][lack of taste character]	sweet watery	acidic high CO_2	
G	BC	malty fruity	sweet high CO_2 lack of taste character	acidic	bitter
H	BC	malty bitter	lack of taste character high CO_2, low CO_2 caramel, acidic	sweet	
K	BC	bitter fruity	malty high CO_2 lack of taste character	sweet acidic	
M	CC	hops malty bitter	lack of taste character acidic burnt	sulphidic papery	low CO_2
N	CC	malty bitter	burnt lack of taste character watery	low CO_2	acidic
O	CC	malty acidic sweet	lack of taste character	burnt low CO_2 watery	
R	CC	bitter fruity	watery lack of taste character	low CO_2 acidic	floral

Table 42(b) Proposed reasons for hedonic response to taste of individual beers based on hedonic indices

Beer	Beer Type	Qualities used more in like zone i.e. reasons for liking	Qualities used more in neutral zone	Qualities used more in dislike zone i.e. reasons for disliking	Qualities showing bimodal distributions: like v dislike
A_1	BC	bitter body fullness		sweet acidic high CO_2 lack of taste character	
A_2	BC	bitter body fullness	fruity lack of taste character high CO_2 sweet	acidic	
C	BC		sweet watery	acidic high CO_2	
		[bitter][lack of taste character]			
G	BC	malty	sweet high CO_2 lack of taste character	acidic	bitter
			fruity		
H	BC	malty bitter		sweet lack of taste character high CO_2, low CO_2 caramel[2], acidic[2]	
K	BC	bitter	malty high CO_2 lack of taste character	sweet acidic	
			fruity		
M	CC	hops malty	lack of taste character acidic	sulphidic papery	low CO_2
		bitter	burnt		
N	CC	malty bitter	burnt	low CO_2	acidic
			lack of taste character watery		
O	CC	malty acidic	lack of taste character	burnt low CO_2 watery[2]	
		sweet			
R	CC	bitter	watery lack of taste character	low CO_2	floral
			fruity	acidic sweet	

CC beers both for the whole sample of consumers (see Table 28(a), page 92) and for the sub-divided sample (Table 31, page 97) and did not show a high frequency of use of odour classes associated with low hedonic ratings (i.e. sulphidic, papery, acidic).

Although Table 42(a), p. 129 shows some disparity in the results presented for the duplicate beers A_1 and A_2, the disparity for hops and body fullness odours was small, (5.8% for beer A_1 and 4.3% for beer A_2 for both qualities) and in any case was emphasised by the choice of the 5% minimum level of use. Therefore the greatest difference related to the use of the odour class sweet. Indeed the use of this class as a reason for a hedonic response varied considerably from beer to beer (Table 41(a)). In three beers A_1, C and R it was primarily used in the neutral zone, whereas for beers H and N it was used mainly in the neutral and dislike zones. For beer G it was used mostly as a reason for disliking the beer and in the remaining three beers, A_2, K, and O, the use was divided over the like and dislike scale. The variable use of this quality was also reflected in the average hedonic index which indicated a spread of use over the scale (1.1 : 1.1 : 1.0). The implications of the use of this quality will be discussed on page 134.

The average hedonic index for lack of odour character (4.0 : 5.6 : 1.0) indicated a greater level of use of this quality over the neutral and dislike regions of the scale and this distribution was shown by all beers. If, as previously suggested (see p. 124), this quality is indicative of blandness, these results show a neutral or somewhat unfavourable opinion being held of beers for which this description was used.

Table 41(b), p. 127 shows that three taste classes were used on average to the greatest extent over the like section of the scale

viz.: malty

bitter

body fullness

These are therefore desirable properties of beer taste.

Four taste classes were used on average to the greatest extent on the dislike scale

viz.: sulphidic
papery
acidic
low CO_2

These are therefore undesirable properties of beer taste.

In the case of the hops taste, the index was bimodal with high frequencies of use occurring at both the like and dislike ends of the scale. In the case of six taste classes, caramel, burnt, sweet, high CO_2, watery and lack of taste character, the index shows a concentration of use in the neutral and dislike zones, whereas fruity shows a bias towards the neutral and like zones.

As in the analysis of odour classes, taste classes prominent in each beer were separated according to their individual hedonic indices in order to conclude reasons, in terms of taste properties, for the hedonic responses for each beer (Table 42(b), p.130). In the case of CC beer M, taste classes related to a definite favourable response to this beer were hops and malty, while, conversely, sulphidic and papery were associated with an unfavourable response. Bitter taste was associated with both the neutral zone and like zone and acidic and burnt with both the neutral and dislike zones. These results confirm the explanation for bimodality shown earlier in the analysis of odour classes (page 128); the exception being the indiscriminate use of the malty class (see page 124). It is possible that the consumers could detect a prominent taste in this beer and failed to identify it correctly, thereby applying the term malty indiscriminately.

CC beer O was the only beer in which the bitter taste class was not used above the 5% minimum (Table 41(b) , p. 127). A further observation

unique to beer O is the predominant use of the acidic taste class over the like end of the scale (Table 42(b), p. 129). As use of the acidic odour class showed indisputably that it was associated with dislike, it is possible that the use of the classes for these two basic tastes, bitter and acidic were confused by the consumer for this beer. This possibility will be discussed on page 135.

Some confusion arose over the use of the hops and floral taste classes for beer R. Whereas the hops class was used more frequently for this beer in the case of odour, the floral class was used most frequently for taste. Results from the trained panel have shown these qualities to be closely associated for both flavour-in-mouth and aftertaste and therefore it may be concluded that this confusion by the consumer was not entirely unexpected.

The greatest difference between the duplicate beers A_1 and A_2 was in the use by the consumer of the fruity taste class (Table 38(b), page 117). Reasons for liking were the same for both these beers (Table 42(b), page 130) and there was a slight difference in the use of sweet, high CO_2 and lack of taste character. The variability of the sweet taste class (Table 41(b), page 127) is marginally less than that shown by the corresponding odour class (page 131), with the sweet taste class being a reason for disliking three beers (A_1, H and K) and being used in the neutral to dislike zones for a further two beers (A_2 and R). Of the remaining three beers, for which the taste class was used by more than 5% of consumers, beers C and G showed that the quality was used most in the neutral zone and for beer O it was used more in the neutral to like zone.

The average hedonic index of lack of taste character (3.8 : 4.6 : 1.0) shows agreement with the predominant use of the corresponding odour quality over the neutral and dislike regions of the scale. Once again this suggests a somewhat unfavourable opinion being held of beers for which this description was used.

Previous attempts to interpret subjective descriptions from consumers[70,124] have lacked a basic foundation upon which terms could be classified. The use of the International System of Beer Flavour Terminology[60] therefore provided a unique opportunity to assess the descriptive ability of the consumer, while allowing some comparisons to be made with these other published works.

It was observed by Lehrer that different assessors found different aspects of the sensory properties of wine salient.[70] If qualities do possess various levels of saliency, the bimodality in hedonic responses discussed on page 128 could have been due to different qualities prominent in that beer. Thus, for beer M, the high intensity of sulphidic odour and taste qualities could have been more salient to those consumers who found the beer unpleasant, whereas the high intensity of hop odour and taste were more important to those who found the beer pleasant. This would also explain why sulphidic qualities were used more at the dislike end of the scale and hop qualties more at the like end. Lehrer also showed that the variable use of descriptions applied to wine depended on whether or not the taster liked the wine.[70] Certain words became evaluative as well as descriptive, an effect which could be assessed, to some extent, by their association with other qualities. This effect could explain the variable use of the odour and taste classes 'sweet' across the hedonic scale. Used in an evaluative manner, those consumers regarding sweet odour or taste as a desirable quality in beer would reserve it for beers they liked, whereas those believing this quality to be undesirable would only use it to describe beers they disliked. (The significant correlation between use by the consumers of this odour class (Table 39(a)) and taste class (Table 39(b)) with intensities from the trained assessors also show this quality to be a reliable descriptive quality (see pages 119,120).

Commenting on the confusion between sour and bitter tastes, Lehrer concluded that both tastes were antonyms for sweet, proposing that taste sensations could conveniently be described as sweet, salt or

unpleasant.[70] Confusion between sour and bitter sensations, (believed to exist in this instance in the case of beer O, (see page 133) were also reported by Robinson[69] who disagreed with earlier work by Meislmann and Dzendolet who proposed that such confusion was physiological in origin and could be regarded as the gustatory analogue to abnormal colour vision.[125] Robinson argued that the difficulty was not one of discrimination but one of naming the perceived sensation, mainly due to the rarity of bitterness in foods.[69] Robinson also proposed that the term bitter was used primarily to describe unpleasant sensations,[69] its most common use being to describe strong, sour (acidic) notes. This argument cannot be applied to bitter beers, a drink in which a degree of bitterness is regarded as a necessary and desirable quality, an observation supported by the hedonic index for this quality (1.0 : 1.2 : 1.4). In another consumer survey it has been shown that the subjective acceptability of bitterness in beer by consumers can influence their ability to objectively rate beers for this taste quality.[80] This would suggest that bitterness can be an evaluative as well as a descriptive quality.

For this reason Holland sought some form of rationalisation in the meaning of words used by consumers in which he described several forms of common confusion.[124] In one form, rather than giving their own opinion, consumers used words they thought ought to be used, whether or not they understood their meaning. This form of error is comparable with the use of words with an expected or purely evaluative meaning as described above.

Despite the obvious problems, this section of the research has attempted to show that using an established vocabulary to classify descriptive terms and employing methods of validation of the use of these terms, it is possible to reach a better understanding of the reasons for preferences for the beers. As such, the descriptive terms were inseparably related to stated preferences and did not test fully the ability of the

consumer to detect and describe the prominent odour and taste qualties in beer. The next section seeks to test this ability by divorcing the assessment of the odour and taste of beers by the consumer from any preference analysis.

C. (iii) Recognition of pre-selected odour qualities (Question 14, page 83) and (vii) pre-selected taste qualities (Question 17, page 84)

The total frequency of use of each pre-selected odour quality for each beer is shown in Table 43(a) and that of each pre-selected taste quality is shown in Table 43(b), p. 137.

Table 43(a) Total frequency of use of pre-selected odour qualities

Pre-selected odour qualities	Beers										Input to multiple regression analysis*
	A_1	A_2	C	G	H	K	M	N	O	R	
sweet	53	35	44	40	36	51	14	22	23	37	x_1
fruity	34	39	38	36	22	39	24	36	23	59	x_2
caramel, toffee, malty	53	59	73	66	104	57	43	39	42	46	x_3
like flowers (hops)	19	28	14	10	4	18	14	16	22	32	x_4
sharp, sour	31	27	27	42	37	32	35	49	35	43	x_5
burnt	13	25	12	21	19	25	36	17	29	10	x_6
rotten	7	6	5	14	19	11	90	24	37	8	x_7
Beer type	BC	BC	BC	BC	BC	BC	CC	CC	CC	CC	
Mean hedonic score * for whole scale	5.6	5.5	5.9	5.4	4.6	5.2	4.2	4.9	4.4	5.2	y_1
Mean hedonic score * for dislike sclale	3.8	3.9	4.0	3.6	3.0	3.6	2.2	3.4	3.0	3.3	y_2
Mean hedonic score * for like scale	6.5	6.5	6.6	6.5	6.7	6.6	7.1	6.4	6.4	6.8	y_3

Footnote to Table 43(a) * For an explanation of the significance of these figure see page 146.

Table 43(b) Total frequency of use of pre-selected taste qualities

Pre-selected taste qualities	Beers										Input to multiple regression analysis*
	A_1	A_2	C	G	H	K	M	N	O	R	
sweet	18	34	56	49	29	57	11	8	24	33	x_1
caramel, toffee, malty	32	38	58	48	78	59	54	27	42	32	x_2
like-flowers (hops)	11	10	14	16	11	26	32	19	15	67	x_3
sharp sour	62	59	31	45	36	34	103	74	69	66	x_4
bitter	66	57	47	58	42	28	56	73	49	40	x_5
fizzy	75	83	43	48	45	35	7	5	11	7	x_6
smooth	14	29	38	46	51	65	36	51	69	36	x_7
Beer type	BC	BC	BC	BC	BC	BC	CC	CC	CC	CC	
Mean hedonic score * for whole scale	5.4	5.6	5.7	5.8	5.1	5.4	3.8	4.1	4.6	4.3	Y_1
Mean hedonic score * for dislike scale	3.5	3.5	3.2	3.5	3.3	3.1	2.0	2.7	2.8	2.6	y_2
Mean hedonic score * for like scale	6.7	6.9	6.8	6.9	6.7	6.9	7.3	6.7	6.7	7.0	y_3

Footnote to Table 43(b) * For an explanation of the significance of these figures see page 146.

The data in Tables 43(a) and 43(b) were analysed in three ways:

(a) Correlation with results from trained panel.

(b) Factor analysis.

(c) Multiple regression against preference ratings

(a) Correlation of frequencies of use of pre-selected odour and taste qualities (consumer survey) with intensities of appropriate odour and taste qualities (assessed by trained panel)

Unlike the odour and taste descriptions associated with preference ratings presented in the previous section, the use of pre-selected odour and taste qualities was designed to test the ability of the consumer to describe the perceived odour and taste of the beers. It was considered that the more prominent odour and taste qualities (i.e. those with the highest intensities as determined by the trained panel) would be more easily recognised by the consumer. Hence the consumers' frequency of use

of these qualities would be high. This led to the presently attempted correlation.

Comparison was achieved by determining the degree of correlation between (a) the frequency of use by the consumer of the pre-selected odour or taste qualities and (b) the intensity of the appropriate odour or taste qualities in the same beers as determined by the trained assessors. Because of the multiple nature of some of the pre-selected qualities (decided on the basis of the results of the earlier factor analysis (page 85), every possible correlation was made vs. the appropriate quality used by the trained assessors (Table 44(a) below and 44(b) page 139).

Table 44(a) Correlation between frequency of use by consumers of pre-selected odour qualities and intensities determined by trained assessors

Pre-selected odour qualities used by consumers	Corresponding qualities used by trained assessors	Correlation coefficient ($\times 10^3$)	Significant differences (see footnote)
sweet	sweet	+ 865 *	1
fruity	fruity citrus	+ 597 *	
fruity	fruity other	+ 242	1
caramel toffee malty	caramel toffee	+ 712 *	2
caramel toffee malty	malty	+ 670 *	1
like flowers	hops	+ 531	1 2
like flowers	floral fragrant	+ 079	1
like flowers	herbal	+ 288	
sharp sour	sour, acidic, sharp	+ 241	2
burnt	burnt roasted	+ 334	1
rotten	rotten putrid	+ 965 *	1
rotten	onions garlic	+ 970 *	1
rotten	burnt rubber	+ 917 *	1

Footnote to Table 44(a) * Correlation significant at $p \leq 0.05$, i.e. correlation coefficient ($\times 10^3$) > ± 564

1. Trained assessors showed that odour of individual beers differed significantly in this quality ($p \leq 0.05$).
2. Trained assessors showed that odour of the beer types differed significantly in this quality ($p \leq 0.05$).

Results gave four significant correlations for pre-selected odour qualities (i.e. sweet; fruity; caramel toffee malty; and rotten), six significant correlations for pre-selected taste qualities with flavour-in-mouth qualities (ie. sweet; caramel toffee malty; like

flowers; sharp sour; bitter and smooth) and four significant correlations for pre-selected taste qualities with after-taste qualities (i.e. sweet; caramel toffee malty; like flowers and smooth).

Table 44(b) Correlation between frequency of use by consumers of pre-selected taste qualities and intensities determined by trained assessors

Preselected taste qualities used by consumers	Corresponding qualities used by trained assessors	Correlation coefficient flavour-in-mouth ($x10^3$)	Correlation coefficient aftertaste ($x10^3$)	Significant differences (see footnote)
sweet	sweet	+ 762 *	+ 718 *	5,6
caramel toffee malty	caramel toffee	+ 410	- 059	5
caramel toffee malty	malty	+ 590 *	+ 709 *	5
like flowers	hops	+ 870 *	+ 881 *	4 6
like flowers	floral fragrant	+ 461	+ 836 *	5,6
like flowers	herbal	+ 496	+ 616 *	——
sharp sour	sour acidic sharp	+ 761 *	- 256	5
bitter	bitterness	+ 573 *	+ 261	3,4,5,6
fizzy	CO_2 tingle	+ 516	+ 359	5
smooth	smooth mellow full bodied	+ 681 *	+ 610 *	——

Footnote to Table 44(b) * Correlation significant at $p \leq 0.05$, i.e. correlation coefficient ($x10^3$) > ± 564

3. Trained assessors showed flavour-in-mouth of individual beers differed significantly in this quality ($p \leq 0.05$).
4. Trained assessors showed aftertaste of individual beers differed significantly in this quality ($p \leq 0.05$).
5. Trained assessors showed flavour-in-mouth of beer types differed significantly in this quality ($p \leq 0.05$).
6. Trained assessors showed aftertaste of beer types differed significantly in this quality ($p \leq 0.05$).

These results therefore show yet another instance of agreement in descriptive analysis between a trained laboratory panel and a consumer panel. The results suggest that consumers were more proficient at describing sweet, fruity, caramel toffee malty and rotten odours and sweet, caramel toffee malty, like flowers, sharp sour, bitter and smooth tastes than they were at describing like flowers, sharp sour and burnt odours or fizzy tastes. This shows considerable agreement with the result from the

previous section (Tables 39(a) and (b), pages 119 and 120) where the use of odour classes malty, sulphidic, sweet and taste classes floral, sweet, acidic, by the consumers, as reasons for preference, showed significant correlation with the intensities of these particular qualities in beers as determined by trained assessors ($p \leq 0.05$).

In order to analyse beer types, the average frequency of use of each pre-selected odour and taste quality for all individual beers within each type were calculated (Tables 45(a) and (b), below).

Table 45(a) Average frequency of use of the pre-selected odour qualities for the two beer types

Pre-selected odour quality	Average frequency for BC beers	Average frequency for CC beers	Difference between types	Predominating beer type
sweet	43.2	24.0	19.2	BC
fruity	34.7	35.5	0.8	CC
caramel, toffee, malty	68.7	42.5	26.2	BC
like-flowers (hops)	15.5	21.0	5.5	CC
sharp, sour	32.7	40.5	7.8	CC
burnt	19.2	23.0	3.8	CC
rotten	10.3	39.8	29.5	CC

Table 45(b) Average frequency of use of the pre-selected taste qualities for the two beer types

Pre-selected taste quality	Average frequency for BC beers	Average frequency for CC beers	Difference between types	Predominating beer type
sweet	40.5	19.0	21.5	BC
caramel toffee malty	52.2	38.8	13.4	BC
like flowers	14.7	33.3	18.6	CC
sharp sour	44.5	78.0	33.5	CC
bitter	49.7	54.5	4.8	CC
fizzy	54.8	7.5	47.3	BC
smooth	40.5	48.0	7.5	CC

Table 45(a) showed that fruity, like flowers, sharp sour, burnt and rotten odour qualities were used more often for CC beers while sweet,

caramel toffee malty odour qualities were used more often for BC beers. The data shown in Table 43(a), page 136 supports this distinction between the two beer types. Once again this agrees extremely well with earlier conclusions from the trained panel (page 53) and also with those from the consumers' reasons for preference (page 124). Table 45(b) showed that like flowers, sharp sour, bitter and smooth taste qualities were used more often for CC beers while sweet, caramel toffee malty and fizzy taste qualities were used more often for BC beers. In terms of those pre-selected qualities which were common to both the odour and taste assessment by consumers (like flowers, sharp sour, sweet and caramel toffee malty) there is complete agreement as to the distinction between beer types. Furthermore these results from the assessment of taste by the consumer agree extremely well with earlier conclusions from the trained panel (page 53) and also with those from the consumers' reasons for preference (page 124).

(b) Factor analysis of frequency of use of pre-selected odour and taste qualities

A factor analysis was performed to determine how the pre-selected odour qualities were inter-related according to their frequency of use by the consumer. A second factor analysis was performed on the pre-selected taste qualities. The BMDP programme P4M[95] was used, following the procedure described on page 43. The seven pre-selected odour qualities were reduced to three factors which explained 88.8% of the variance (Table 46(a), p. 142). The seven pre-selected taste qualities were also reduced to three factors which explained 86.6% of the variance (Table 46(b), p. 142).

The inter-relationship of odour qualities within these factors (Table 46(a)) shows considerable agreement with the inter-relationship of corresponding odour qualties assessed by the trained panel (Table 10, p. 44). In both cases the negative correlation between sweet, caramel toffee odours and rotten odour was shown in the first factors extracted.

Table 46(a) Factors and factor loadings resulting from factor analysis of the frequency of use of pre-selected odour qualities

Factor 1 (variance explained 42.4%)		Factor 2 (variance explained 29.4%)		Factor 3 (variance explained 17.0%)	
pre-selected quality	loading x 10^3	pre-selected quality	loading x 10^3	pre-selected quality	loading x 10^3
rotten	+ 929	like flowers	+ 941	sharp sour	+ 977
burnt	+ 889	fruity	+ 632		
sweet	- 797	caramel toffee malty	- 828	sweet	- 451
fruity	- 672				
caramel toffee malty	- 350				

Table 46(b) Factors and factor loadings resulting from factor analysis of the frequency of use of pre-selected taste qualities

Factor 1 (variance explained 42.4%)		Factor 2 (variance explained 29.1%)		Factor 3 (variance explained 15.1%)	
pre-selected quality	loading x 10^3	pre-selected quality	loading x 10^3	pre-selected quality	loading x 10^3
sharp sour	+ 872	like flowers	+ 990	smooth	+ 912
bitter	+ 789	sharp sour	+ 311	caramel toffee malty	+ 456
sweet	- 928	fizzy	- 580	fizzy	- 685
caramel toffee malty	- 599	bitter	- 377	bitter	- 365
fizzy	- 361				

Both analyses also showed the negative correlation between caramel toffee malty and hop associated (like flowers) odour qualities. Similarly the inter-relationship of taste qualities within the factors (Table 46(b)) also showed considerable agreement with the inter-relationship of corresponding

taste qualities assessed by the trained panel (Tables 11, 12, p. 45, 46). The negative correlation between bitter and fizzy, sweet tastes in factor one (Table 46(b)), corresponded to that found by the trained assessors and extracted in flavour-in-mouth factor 6 (Table 11). The negative correlation between bitter and caramel toffee in factor one in Table 46(b) also corresponded to that found by the trained assessors and extracted in aftertaste factor four (Table 12). The positive correlation between the basic tastes bitter and sharp sour in factor one (Table 46(b)) suggest similar use of these terms by the consumer. Although at first sight this may suggest some confusion by the consumer in the use of these qualities, hedonic indices of bitter and sharp sour taste classes of 1.0 : 1.2 : 1.6 and 2.1 : 1.3 : 1.0 respectively, show selective use of these qualities by the consumer, to describe likes and dislikes. Furthermore, while there was some apparent confusion by consumers over the use of these taste classes for beer 0 (page 132) the frequency of use by consumers of both the pre-selected qualities, correlated significantly ($p \leq 0.05$) with intensities determined by the trained panel for corresponding flavour-in-mouth qualities. These results suggest that the association shown by the consumers between bitter and sharp sour tastes in the beers was largely justified and did not detract from their ability to recognise these qualities in specific beers, or to use them, in most cases, as reliable reasons for preference. The inter-relationships between taste qualities in factors two and three (Table 46(b)) are conflicting and inexplicable. It is interesting to note that sweet and caramel toffee malty qualities were positively correlated and extracted in the first factor in the analysis of both the odour and taste data (Tables 46(a) and (b)).

These results indicate substantial agreement between consumers and trained assessors in the perception of certain odour and taste qualities within the overall flavour complex and adds further support to the ability of the consumer to perceive and describe prominent qualities in beer.

(c) Stepwise multiple regression of frequencies of use of pre-selected odour and taste qualities vs. preference ratings

This analysis was performed in an attempt to explain trends in odour and taste preferences (page 92) in terms of the frequency of use of the pre-selected odour and taste qualities. The relationship between these two sets of data was examined by a series of multiple regression analyses, with mean hedonic scores of beers as the dependent variable (y), and the frequency of use of each pre-selected odour (or taste) quality for that beer as the independent variable (x_1). The linear least squares model with regression coefficients b_i can be written

$$y = a + b_1x_1 + b_2x_2 + - - - - + b_px_p + e$$

where y = dependent variable (mean hedonic score)

$x_1 - - - x_p$ = independent variables (frequency of use of pre-selected odour or taste qualities)

$b_1 - - - b_p$ = regression coefficients

a = the intercept

p = the number of independent variables

e = the error with mean zero

Regression analysis has several basic applications, including (i) characterisation of relationships between dependent and independent variables, (ii) production of quantitative equations to predict the dependent variables as a function of the independent variables and (iii) determination of the degree of importance of each independent variable in predicting or determining the dependent variable.[126] In this instance the main area of interest was to determine the relative contribution of the pre-selected qualities to the variation of mean hedonic scores.

A stepwise method of multiple regression analysis was used employing the BMDP P2R[127] computer programme which calculates the F-ratio as a test of significance of the coefficients of the independent variables in the equation. The variables were then selected for inclusion into the equation in a manner that maximised the F-ratio; thus independent

variables entered the equation in order of magnitude of their F-ratios. Maximum and minimum F-ratio limits were imposed to prohibit entry of independent variables with F-ratios outside this pre-determined range. The statistics that were of major importance to this study were the multiple regression coefficient (multiple R^2) and the beta coefficient (β). The former represents the proportion of variance of the dependent variable explained by the independent variables. This was expressed as a percentage; thus the higher this percentage the greater the variation of mean hedonic scores explained by the frequencies of the pre-selected odour (or taste) qualities. The β coefficient for standardised variables was definied as:

$$\beta = b_i \cdot \frac{s_i}{s_y}$$

where β = beta coefficient
b_i = partial regression coefficient
s_i = standard deviation of independent variable
s_y = standard deviation of dependent variable

The β coefficients reflect the nett effect of each independent variable (each pre-selected odour or taste quality) on the dependent variable (mean hedonic score).

In order to assess this, each β coefficient was converted to a percentage of the absolute sum of all β coefficients.[128] The sign of the β coefficients indicated the relationship between each independent and dependent variable, a positive β coefficient indicating that as the value of x (frequency of use of a pre-selected odour/taste quality) increased, so too does the value of y (mean hedonic score). This represents a positive slope. A negative β coefficient therefore denotes a negative slope.

The data used for these regressions are shown in Table 43(a) and (b) pages 136 and 137. In earlier analyses, the hedonic scale was divided into three sections (page 124). For this present analysis a

simpler division was initially thought possible, whereby the scale was divided into like and dislike sections. Initially it was intended that analysis of the divided scales would indicate any variation that might exist between the association of the frequency of use of the pre-selected odour or taste qualities, and the strength of the responses from those consumers who liked a beer (shown by mean hedonic score on the like scale) and the strength of the responses from those who disliked a beer (shown by mean hedonic score on the dislike scale). However, inspection of the mean hedonic scores for each beer on the divided scales showed that the bimodal distribution earlier discussed (page 128), caused certain beers (especially beers M and R) to have low mean hedonic scores on the dislike scale and high mean hedonic scores on the like scale. Thus, of all the beers assessed by the consumer, these beers were both liked and disliked more than the other beers. A single regression analysis on the undivided scale (as seen in other publications) would not reveal this effect and therefore equations were constructed for each of the three scales and the results compared. Equations were therefore constructed for the three dependent variables (y_1, y_2 and y_3) for (a) odour and (b) taste. y_1 was the mean hedonic score for each beer; y_2 was the mean hedonic score for the dislike scale (scores 1-4 inclusive); y_3 was the mean hedonic score for the like scores (scores 6-9 inclusive); half the scores of 5 from the rating scale were included in y_2 and the other half in y_3.

The independent variables (x_1 to x_7) remained constant in each equation.

The results for the odour qualities (Table 47(a), p. 147) successfully explained over 90% of the variance in mean hedonic scores for equations y_1, y_2 and y_3. On the whole scale (y_1, Table 47(a)(i)) and on the dislike scale (y_3, Table 47(a) (iii)) an increased frequency of use of the majority of odour qualities corresponded to a decrease in mean hedonic scores. This means that as more consumers detect more odour qualities, a lower preference results. This did not apply to the like scale (y_2, Table 47(a)(ii)

Table 47(a) Results of stepwise multiple regression analyses of frequency of use of pre-selected odour qualities (x) vs. mean hedonic scores (y) for all beers

Pre-selected odour qualities	(i) whole scale (y_1) beta coefficients	% contribution to variation	direction of contribution to hedonic response	(ii) like scale (y_2) beta coefficients	% contribution to variation	direction of contribution to hedonic response	(iii) dislike scale (y_3) beta coefficients	% contribution to variation	direction of contribution to hedonic response
sweet	-	-	-	+0.466	10.5	increase	-	-	-
fruity	+0.692	21.1	increase	+0.728	16.4	increase	-	-	-
caramel toffee malty	-0.521	15.9	decrease	+0.841	19.0	increase	-0.534	22.3	decrease
like-flowers (hops)	-0.781	23.8	decrease	+0.333	7.5	increase	-0.387	16.2	decrease
sharp, sour	-0.599	18.2	decrease	-	-	-	-0.350	14.6	decrease
burnt	-	-	-	-0.181	4.1	decrease	-	-	-
rotten	-0.690	21.0	decrease	+1.882	42.5	increase	-0.119	46.8	decrease
multiple R^2	91.8%			99.2%			94.3%		

Table 47(b) Results of stepwise multiple regression analyses of frequency of use of pre-selected taste qualities (x) vs. mean hedonic scores (y) for all beers

Pre-selected taste qualities	(i) whole scale (y_1) beta coefficients	% contribution to variation	direction of contribution to hedonic response	(iii) dislike scale (y_3) beta coefficients	% contribution to variation	direction of contribution to hedonic response	(ii) like scale (y_2) beta coefficients	% contribution to variation	direction of contribution to hedonic response
sweet	+0.548	36.2	increase	+1.025	29.3	increase	-	-	-
caramel toffee malty	-	-	-	+0.509	14.5	increase	-0.444	1.6	decrease
like flowers	-0.117	7.7	decrease	+0.223	6.4	increase	+0.286	10.7	increase
sharp sour	-0.201	13.3	decrease	+1.476	42.1	increase	-0.576	21.6	decrease
bitter	+0.182	12.0	increase	-	-	-	+0.453	17.0	increase
fizzy	+0.467	30.8	increase	-	-	-	+0.915	34.3	increase
smooth	-	-	-	-0.271	7.7	decrease	+0.396	14.8	increase
multiple R^2	98.3%			97.7%			94.0%		

however, where an increased frequency of use of most odour qualities corresponded to an increase in mean hedonic ratings. This apparent conflict may be explained, in part, by the bimodal distribution of hedonic scores for certain beers (page 100), especially beer M, which had the highest frequency of use of the rotten odour quality and the lowest frequency of use of the sweet odour quality, together with extreme hedonic means on all three scales (see Table 43 (a)). It is likely therefore that such beers could bias the relative contribution (and possibly also affect the direction of contribution) of certain odour qualities to mean hedonic score variations.

The results for the taste qualities (Table 47(b)) successfully explained over 90% of the variance in mean hedonic scores for equations y_1, y_2 and y_3. Unlike the situation with odour qualities on the whole scale, in which any increase in frequency of use of a quality corresponded to a decrease in preference, (page 146) increased frequency of use of certain taste qualities (i.e. sweet, bitter and fizzy) corresponded to an increased preference (Table 47(b)(i)). Similarly on the dislike scale, like flowers, bitter, fizzy and smooth taste qualities all corresponded to increased preference. On the whole scale sweet, bitter and fizzy corresponded to an increase in preference and accounted for 78.5% of the variance explained. Like flowers and sharp sour corresponded to a decrease in preference and accounted for the remaining 21.5% of the variation. On the like scale (Table 47(b)(ii)), sharp sour corresponded to an increase in preference and accounted for 42.1% of the variance explained. This was thought to be a direct effect of the bimodal distribution of beer M. Despite this effect, sweet taste also contributed highly to the variance on the like scale and although the high frequency of use of sharp sour taste for beer M affected the equation for the dislike scale (Table 47(b)(iii)), the most dominant quality in this case was fizzy taste.

Since the dominance of such pre-selected qualities as rotten odour and sharp sour taste in beer M probably accounted for the bimodality of this beer it was possible that this was selectively affecting the

regression analysis. Therefore, regression equations were re-calculated for dependent variables y_1, y_2 and y_3, for (a) odour and (b) taste, with beer M excluded from the analysis. In this way the effect of the exclusion of this single beer could be assessed (Tables 48(a) and (b), p.150).

In the case of odour (Table 48(a)), the exclusion of beer M did cause certain specific changes, e.g. on the whole scale this exclusion increased the contribution of sweet, caramel toffee malty odour qualities (both with low frequencies of use for this beer) to the variation in mean hedonic ratings and eliminated the fruity odour contribution. Exclusion of beer M also decreased the relative contribution of rotten odour on both the like and dislike scales (y_2, y_3 Table 48(a)(ii)(iii)) but owing to the relatively high frequency of use of this quality for beers O and N and their low mean hedonic scores on the whole hedonic scale (y_1 Table 43(a)), the contribution of rotten odour increased (Table 48(a) (i)). However, despite these specific changes, the exclusion of beer M did not alter the direction of contribution of odour qualities corresponding to decreases in hedonic response on the whole scale and dislike scale nor to increases on the like scale. Therefore, in the case of analysis of the odour qualities it appeared that the exclusion of beer M merely altered the relative contribution of certain odour qualities to preference variations.

Exclusion of beer M from analysis of the taste data had the same effect as that already described for the odour data, i.e. the relative contribution of certain taste qualities was changed but the direction of their contribution remained the same. On the whole scale (Table 48(b)(i)), the exclusion of beer M increased the relative contribution of taste qualities sweet and fizzy, and eliminated sharp sour from the equation. As beer M showed a high frequency of use by the consumer of the sharp sour quality, and low frequency of use of sweet and fizzy qualities, this is a logical result. One of the greatest single effects of the exclusion of

Table 48(a) Results of stepwise multiple regression analysis of frequency of use of pre-selected odour qualities (x) vs.mean hedonic scores (y), excluding CC beer M from analysis.

Pre-selected odour qualities	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response
	(i) whole scale (y_1)			(ii) like scale (y_2)			(iii) dislike scale (y_3)		
sweet	-0.333	9.8	decrease	+0.523	11.6	increase	-0.556	12.3	decrease
fruity	-	-	-	+1.239	27.5	increase	-0.012	0.3	decrease
caramel toffee malty	-0.745	22.0	decrease	+1.311	29.1	increase	-1.036	23.0	decrease
like-flowers (hops)	-0.678	20.0	decrease	+0.419	9.3	increase	-0.925	20.5	decrease
sharp, sour	-0.380	11.2	decrease	-	-	-	-0.659	14.6	decrease
burnt	-	-	-	-	-	-	-	-	-
rotten	-1.257	37.0	decrease	+1.010	22.4	increase	-1.321	29.3	decrease
multiple R^2	94.6%			95.0%			98.7%		

Table 48(b) Results of stepwise multiple regression analysis of frequency of use of pre-selected taste qualities (x) vs.mean hedonic scores (y), excluding CC beer M from analysis.

Pre-selected taste qualities	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response	beta coeff-icients	% contri-bution to var-iation	direction of contri-bution to hedonic response
	(i) whole scale (y_1)			(ii) like scale (y_2)			(iii) dislike scale (y_3)		
sweet	+0.689	43.6	increase	+0.915	36.2	increase	-	-	-
caramel toffee malty	-	-	-	-	-	-	-	-	-
like-flowers	-0.207	13.1	decrease	+0.673	26.6	increase	-	-	-
sharp, sour	-	-	-	+0.550	21.7	increase	-0.328	19.4	decrease
bitter	+0.151	9.6	increase	-	-	-	+0.276	16.3	increase
fizzy	+0.532	33.7	increase	+0.391	15.5	increase	+0.901	53.3	increase
smooth	-	-	-	-	-	-	+0.187	11.1	increase
multiple R^2	97.9%			89.7%			95.5%		

beer M was the decreased contribution of sharp sour on the like scale (Table 48(b)(ii)). Due to the high frequency of use by the consumer of like flowers for beer R, which also had the highest mean hedonic score on the like scale after removal of beer M, the contribution of this quality was seen to increase considerably. The contribution of sweet also increased and fizzy entered the equation. On the dislike scale the relative contribution of fizzy taste increased dramatically when beer M was excluded and caramel toffee and like flowers were removed from the equation.

It may be concluded from these results that the removal of beer M, the beer with the greatest bimodality of hedonic response, caused considerable changes with respect to the relative contribution of odour and taste qualities to the equation explaining the variation in preferences. However, the direction of their contribution remained unchanged.

Individual pre-selected odour qualities contributing most consistently to the equations were caramel toffee malty and rotten. Tables 47(a), 48(a), p. 147, 150 show that prominence of either of these qualities can correspond to either a decrease in preference (whole scale and dislike) scale) or an increase in preference (like scale). Sharp sour and like flowers odours contributed more consistently to the whole and dislike scales, being associated with decreases in preference in both cases. Use of the odour class acidic (hedonic index 8.7 : 4.3 : 1.0) by the consumers to describe reasons for preference was concentrated on the dislike section of the hedonic scale and this supports the relationship described here. However, the association of like flowers (or hop qualities) with decreases in hedonic ratings is contrary to the hedonic index for hop odour, i.e. 1.0 : 2.5 : 6.7. A possible explanation for this disparity is the apparent difficulty of the consumer to recognise this odour quality in beers as demonstrated by the non-significant correlation between consumers' frequency of use and odour intensity as determined by trained

assessors (Table 44(a), page 138). Sweet and fruity odour qualities did not contribute consistently to trends in preference although there were indications that prominence of a fruity odour was associated with an increase in preference (Table 47(a), p. 147). Burnt odour was rarely included in the equation and therefore showed little direct relationship with trends in preference.

In many instances, frequency of use by consumers of relevant pre-selected odour qualities were shown to correspond with preference variations. Analysis of the whole scale indicated that the higher the frequency of use of any prominent odour quality, especially caramel toffee malty or rotten, the lower the preference. This does not take account of the bimodality of hedonic responses however, and when the hedonic scales were divided this effect was shown very clearly. Thus, since the beers with bimodal distributions were also those with prominent odour qualities, high frequencies of use of these qualities corresponded with increases in hedonic ratings on the like scale and decrease on the dislike scale, i.e. some odour qualities being desirable to some consumers and undesirable to others. Such additional information can be used to assess the effect of prominent qualities of a beer on its hedonic distribution. For example, the exclusion of beer M from the analysis highlighted the effect of the low intensity of sweet odour and high intensity of rotten odour in this beer, as determined by trained assessors and recognised by the consumers. Results of this analysis therefore suggest that sweet and rotten odour qualities were directly related to the hedonic responses to this beer.

These results have a particular significance to the concept of blandness earlier discussed (page 58). Since prominent odour qualities have been shown to be associated with extreme preference ratings, a bland product would be less likely to evoke a dramatic hedonic response. If, as these results suggest, such prominent odour qualities have an <u>overall</u> effect of lowering preference, a bland beer would receive a greater

overall preference rating. As such, a bland beer would be disliked less and on balance would appeal to a greater proportion of consumers.

Individual pre-selected taste qualities contributing most consistently to the equations for taste were sweet and fizzy (Tables 47(b) and 48(b)) and prominence of either of these qualities corresponded to an increase in preference. Whilst both taste qualities were dominant on the whole scale, sweet had the greatest effect on the equation for the like scale, corresponding to an increase in liking, and fizzy had the greatest effect on the equation for the dislike scale, also corresponding to an increase in preferences (or a decrease in degree of dislike). The importance of sweet and fizzy taste implied by this analysis was not reflected in the hedonic indices of these qualities. It must therefore be assumed that the relative importance of these qualities is not immediately apparent to the consumer and were therefore not given as reasons for preference. 'Like flowers' corresponded to a decrease in preference on the whole scale due mainly to the low hedonic ratings for the CC beers for which this quality had high frequency of use by the consumers. When beer M was excluded, like flowers taste increased its contribution to the decrease in preference due mainly to beer R (see page 151). Bitter taste only appeared in the equations for the whole scale and the dislike scale, and was always associated with an increase in preference, although it did not explain more than 17% of the variation at any time. The direction of the contribution of this quality did however agree with its hedonic index of 1.0 : 1.2 : 1.6. Sharp sour taste was very dependent on the effect of bimodality, its variable association with preference ratings being demonstrated by the exclusion of beer M from the analysis. The persistent contribution of sharp sour taste to an increase in preference on the like scale (Table 47(b) (ii) and 48(b) (ii)) could have been due to the close relationship of this quality with bitter taste as demonstrated in the previous factor analysis (page 141) and discussed on page 143. Neither caramel toffee malty nor smooth taste were closely related to

variations in preference and were rarely indicated in the equations.

Therefore, as with odour qualities, frequency of use by consumers of relevant pre-selected taste qualities corresponded, in many instances, with preference variations. However unlike the analysis involving odour qualities, in which the direction of contribution was essentially static on all scales, the analysis of taste qualities revealed considerable directional flexibility on all three scales. Thus, while any increase in frequency of use of pre-selected odour qualities on the whole scale corresponded to a decrease in preference, taste qualities such as sweet and fizzy consistently corresponded to increases in preference on the whole scale while other qualities, such as like flowers, consistently corresponded to decreases in preference on this scale. This suggests that while consumers may reject a beer with prominent odour qualities they are more selective about certain prominent taste qualities such as sweet and fizzy.

Since 'tasting' is more akin (than smelling) to the normal drinking situation, during which an assessment of desirable and undesirable qualities would be made, the consumer may become more selective and hence taste qualities are given different levels of acceptability. Thus, while a consumer may prefer a beer with a bland odour, he will also expect a beer to exhibit certain prominent taste qualities. As in the analysis of the pre-selected odour qualities, division of the hedonic scale revealed the dominant influence of certain taste qualities particularly sharp sour which repressed the contribution of other qualities (such as sweet and fizzy) to the equation. Once again this information can be used to assess the effect of prominent taste qualities of a beer on its hedonic distribution. For example, the exclusion of beer M from the analysis highlighted the effect of its low intensity of sweet and fizzy taste and high intensity of sharp sour taste in this beer as determined both by trained assessors and also recognised by the consumers. Results of this analysis

therefore suggest that sweet, fizzy and sharp, sour qualities were directly related to the hedonic responses to this beer.

Overall, the results from this section indicated considerable ability of the consumer to describe odour and taste qualities prominent in beers. It has also shown that once the important flavour qualities are identified by trained assessors and the descriptive ability of the consumer is established, reasons for trends in preference can be given in terms of measurable sensory qualities such as sweet, caramel toffee malty and rotten odours and sweet and fizzy tastes.

In a number of published examples of consumer surveys, pre-selected flavour qualities have been used in an attempt to determine reasons for preferences for beers.[76-78,80] Such pre-selected qualities included bitterness,[76-78,80] carbonation (gassiness),[76,77] body,[76,77,80] and sweetness.[77] In these examples, no attempt was made either to assess the ability of the consumer to detect or recognise such flavour qualities or to relate consumers' frequencies of recognition with objective sensory data. Information of this type is frequently used to improve the product and give the consumer what he says he prefers. However, unless some check is made of the consumers' ability to detect and recognise the qualities claimed to be responsible for this preference, changes could be made to the product which are either undetectable to the consumer or which fail to meet the undefined need. Indeed Watts reports that attempts to match a product to consumers' requirements for bitterness levels resulted in a lowered preference for the modified beer.[78] In the light of the well documented confusion found in consumers' ability to perceive and describe odours and tastes (see page 13), it would appear that sensory data collected without checking the ability of that particular sample of consumers would be intrinsically unreliable.

In a study designed to compare flavour characterisation of beers by trained and untrained assessors, Clapperton and Piggott

concluded that the comparison of descriptive data from the two types of assessors was justified, although the consumer was consciously unlikely to perceive as many flavour notes.[129] As the results from this project have shown good agreement between results from trained assessors and consumers, and have repeatedly demonstrated the ability of the consumer to detect and identify prominent flavour qualities in the beers, this supports the conclusions of Clapperton and Piggott.[129]

Although there are many published examples of the application of multivariate methods of analysis to sensory analysis, few deal directly with descriptive data obtained from consumers. Two examples of such application are available however.[130,131] Factor analysis was used by Wu et al. to investigate inter-relationships between terms used to describe the flavour of wine.[130] Despite the use of subjective terms (e.g. delicate, mature, etc.), the arrangement of descriptive terms within factors appeared logical. However, as no attempt was made to relate such arrangements to objectively determined sensory qualities present in the wines, it is difficult to assess the true meaning of the results. Multiple regression analysis of the sensory components sweetness, sourness and appearance used by consumers to evaluate acceptability of orange drinks and orange juice, revealed that different combinations of these components explained variations in acceptability of two products.[131] It is important to realise therefore, that in this current research, given a different set of beers, the relative contribution of pre-selected flavour qualities to variations in preference could change.

C. (iv) Ranking pre-selected odour qualities (Question 15, page 83) and pre-selected taste qualities (Question 18, page 84) in order of importance

The distribution of rank positions of the pre-selected odour qualities for the entire consumer sample are shown in Table 49(a) and those for the pre-selected taste qualities in Table 49(b).

Table 49(a) Percentage of sample using rank positions for the pre-selected odour qualities

Pre-selected odour quality	Percentage of sample using each rank position						
	most important	2nd most important	3rd most important	4th most important	5th most important	6th most important	least important
sweet	10.6	17.4	20.8	18.8	18.4	9.7	4.3
fruity	15.5	26.6	25.1	17.9	9.7	2.9	2.4
caramel toffee malty	41.1	19.3	15.0	13.0	6.8	1.9	2.9
like flowers	7.2	8.2	10.1	20.3	29.0	20.3	4.8
sharp, sour	20.3	17.4	16.9	13.5	17.9	10.6	3.4
burnt	3.4	10.1	10.6	12.6	15.0	40.1	8.2
rotten	1.9	1.0	1.0	3.9	3.9	14.5	73.9

Table 49(b) Percentage of sample using rank positions for the pre-selected taste qualities

Pre-selected taste quality	Percentages of sample using each rank position						
	most important	2nd most important	3rd most important	4th most important	5th most important	6th most important	least important
sweet	5.8	9.2	11.1	19.3	23.2	23.7	7.7
caramel toffee malty	20.8	17.9	19.3	17.9	8.7	7.2	8.2
like flowers	5.8	3.4	7.2	14.0	18.8	22.2	28.5
sharp sour	3.9	14.0	14.5	13.5	20.3	15.0	18.8
bitter	29.0	28.0	20.3	9.7	4.8	4.8	3.4
fizzy	1.0	5.8	7.7	14.5	16.4	23.7	30.9
smooth	33.8	21.7	19.8	11.1	7.7	3.4	2.4

The rank positions (1-7) of the pre-selected odour and taste qualities for each consumer were converted to percentiles and then to T-scores[132] (see Table 50).

Table 50 Transformation of rank scores to T-scores

Rank position	Percentile	T-score[132]
1	12.5	38.6
2	25	43.3
3	37.5	46.9
4	50	50.0
5	62.5	53.1
6	75	56.7
7	87.5	61.5

An analysis of variance was performed on the T-scores using the BMDP programme P2V[92], described on page 33. A least significant difference (LSD) test[93] was performed on the means to establish how the pre-selected odour and taste qualities differed significantly ($p \leq 0.05$) (Table 51(a) and (b)).

Table 51 Variation in rank order of importance of pre-selected flavour qualities

(a) Odour qualities

Pre-selected odour quality	Mean rank score	LSD test $p \leq 0.05$
		most important
caramel toffee malty	44.2	
fruity	46.5	
sharp sour	47.7	
sweet	48.7	
like flowers	51.1	
burnt	52.7	
rotten	59.3	
(LSD = 1.09)		least important

(b) Taste qualities

Pre-selected taste quality	Mean rank score	LSD test $p \leq 0.05$
		most important
smooth	44.8	
bitter	45.1	
caramel toffee malty	47.5	
sweet	51.6	
sharp sour	52.0	
like flowers	54.2	
fizzy	54.9	
(LSD = 1.19)		least important

Results for odour qualities (Table 51(a)) show caramel toffee malty to be significantly the most important pre-selected odour quality and rotten to be significantly the least important pre-selected odour quality in the beers ($p \leq 0.05$). Results for taste qualities (Table 51(b)) show smooth and bitter to be significantly the most important pre-selected taste qualities and like flowers and fizzy significantly the least important pre-selected taste qualities in beers ($p \leq 0.05$).

Since previous analyses of descriptive data from these consumers have shown a high degree of reliability and consistency in the use of the pre-selected odour qualities, caramel toffee malty and rotten and the pre-selected taste qualities smooth, bitter and like flowers, these results may be interpreted with some confidence.

The relatively constant rank positions of caramel toffee malty (most important) and rotten (least important) pre-selected odour qualities (Table 51(a)) emphasises their role in influencing consumer preference. This result therefore supports the findings of the multiple regression analysis in which the same odour qualities frequently accounted for the greatest proportion of variance in hedonic ratings (Tables 47(a) and 48(a), p. 147, 150). When the full flavour of beer is assessed in the mouth, the relative importance of these qualities changes quite considerably and the basic tastes bitter, sweet and sharp sour, together with mouthfeal qualities such as fizzy, play an increasingly important role. There is some conflict between the declared lack of regard of the importance of fizzy taste and the close association of this quality with variations in preference as shown by the multiple regression analysis. There are two possible explanations for this conflict. The first suggests that carbonation (or fizziness) is only regarded as important when it is particularly low and therefore fizziness itself is not as crucial as 'flatness' or extremely low carbonation. This is supported by the significant correlation between frequency of use by consumers of the taste class 'low carbonation' with intensity of carbonation determined by trained assessors (page 120). The lack of significant correlation between the taste class 'high carbonation' and the same intensity data would suggest that low carbonation has a more direct relationship with preference. The second explanation for the conflict has already been suggested in another context (page 153), viz. that the consumer is not aware of the relative importance of this quality to their overall preference.

Although beer H was found by the trained panel and consumers alike to have the highest levels of caramel toffee malty odour and taste qualities, this beer was also one of the least preferred BC beers. This suggests that a high intensity of caramel toffee malty alone, is not sufficient to guarantee a high preference rating. It is proposed that it is the inter-relationships of caramel toffee associated qualities with other qualities in the overall flavour complex that have the greatest effect on preference. The next section of this project attempts to assess the direct effect of these inter-relationships of flavour qualities on preference.

Correlation of hedonic ratings (consumer survey) and intensities of flavour qualities (trained panel).

In the first part of this thesis, factors and factor scores (generated for each beer as a result of applying factor analysis to (a) odour, (b) flavour-in-mouth and (c) aftertaste intensity scores from the trained panel) provided a relatively objective measure of the overall flavour complex of each beer (see page 43). It was decided therefore to attempt to explain the variations in preference for beers included in the consumer survey (dependent variable) in terms of the factor scores for each beer (independent variable) using stepwise multiple regression analysis.[127] In order to focus the analysis on the differentiation of beer types, only those factors showing significant difference ($p \leq 0.05$) between beer types were included as independent variables, i.e. odour factors 1, 3, 4 and 6, flavour-in-mouth factors 4, 6 and aftertaste factors 4, 5 and 6 (page 49). Since the precise arrangement of qualities within each factor was likely to contribute to the overall odour, flavour-in-mouth or aftertaste of the beers, all appropriate factors were forced into the equations, these being 3 separate regression equations for (a) odour, (b) flavour-in-mouth and (c) aftertaste. Data used for these analyses are shown in Table 52(a) and (b), p.162. Once again equations for the dependent variable (mean hedonic scores) were constructed for the whole hedonic scale (y_1), the like scale (y_2) and the dislike scale (y_3). Odour factor scores were regressed vs. mean hedonic scores for odour preference; flavour-in-mouth factors scores were regressed vs. mean hedonic scores for taste and finally aftertaste were also regressed vs. mean hedonic scores for taste.

It was earlier shown that owing to the bipolar nature of factors, specific arrangements of related odour, flavour-in-mouth or aftertaste qualities could be attributed to each beer type (page 50). Additionally, during interpretation of the present results from regression analysis, it was possible to locate the factor poles which corresponded respectively to increases and decreases in hedonic ratings. This was

Table 52(a) Data used in stepwise multiple regression analysis of odour factor scores (x_1 - x_4) and mean hedonic scores (y_1 - y_3)

Beer	Odour factor scores				Mean hedonic ratings		
	factor 1	factor 3	factor 4	factor 6	whole scale (y_1)	dislike scale (y_3)	like scale (y_2)
	(x_1)	(x_2)	(x_3)	(x_4)			
A_1	-0.35	+0.11	+0.36	-0.17	5.6	3.8	6.5
A_2	-0.35	+0.11	+0.36	-0.17	5.5	3.9	6.5
C	-0.30	-0.24	+0.34	-0.21	5.9	4.0	6.6
G	-0.26	-0.06	+0.03	-0.12	5.4	3.6	6.5
H	-0.20	-0.52	+0.42	-0.30	4.6	3.0	6.7
K	-0.59	+0.07	-0.12	-0.07	5.2	3.6	6.6
M	+1.62	+0.23	-0.68	+2.07	4.2	2.2	7.1
N	+0.49	+0.06	-0.09	-0.20	4.9	3.4	6.4
O	+0.43	-0.12	+0.19	+0.78	4.4	3.0	6.4
R	-0.25	+0.74	-1.34	-0.35	5.2	3.3	6.8

Footnote to Table 52(a)

1. Only factors 1, 3, 4 and 6 were included since these showed significant differences ($p \leq 0.05$) between beer types.
2. For interpretation of factors 1, 3, 4 and 6 in terms of odour qualities see page 44.

Table 52(b) Data used in stepwise multiple regression analysis of flavour-in-mouth and aftertaste factor scores (x_1 - x_3) and mean hedonic scores (y_1 - y_3)

Beer	Flavour-in-mouth factor score		Aftertaste factor score			Mean hedonic ratings		
	factor 4	factor 6	factor 4	factor 5	factor 6	whole scale y_1	dislike scale y_3	like scale y_2
	(x_1)	(x_2)	(x_1)	(x_2)	(x_3)			
A_1	-0.25	+0.13	-0.09	-0.18	-0.29	5.4	3.5	6.7
A_2	-0.25	+0.13	-0.09	-0.18	-0.29	5.6	3.5	6.9
C	-0.50	-0.19	-0.83	-0.51	-0.06	5.7	3.2	6.8
G	-0.12	-0.62	-0.50	-0.09	-0.43	5.8	3.5	6.9
H	-0.04	-0.06	-0.32	+0.05	+0.23	5.1	3.3	6.7
K	-0.43	-0.58	-0.58	-0.25	-0.22	5.4	3.1	6.9
M	-0.02	+0.05	+0.26	+1.00	-0.01	3.8	2.0	7.3
N	+0.48	+0.14	+0.14	+0.29	+0.42	4.1	2.7	6.7
O	+0.11	+0.37	+0.60	-0.18	+0.18	4.6	2.8	6.7
R	+0.75	+0.50	+0.66	+0.67	+0.12	4.3	2.6	7.0

Footnote to Table 52(b)

1. Only flavour-in-mouth factors 4 and 6 and aftertaste factors 4, 5 and 6 were included since these showed significant differences ($p \leq 0.05$) between beer types.
2. For interpretation of flavour-in-mouth factors 4 and 6 and aftertaste factors 4, 5 and 6 in terms of appropriate qualities see pages 45 and 46.

achieved using a simple convention : whenever the β coefficient was positive, qualities with positive factor loadings (hence the positive pole of the factor) corresponded to increased preference; conversely, whenever the β coefficient was negative, qualities with positive factor loadings corresponded to decreased preference. This can be explained as follows. Qualities with positive factor loadings are negatively correlated with those possessing negative loadings on the same factor. Therefore when beers with relatively high mean hedonic scores also have relatively high intensities of qualities on one pole of a factor, it would be expected that these qualities, and this pole, would be associated with high hedonic ratings. In regression analysis, this association would correspond to an increase in hedonic ratings. Conversely, qualities on the opposite pole of the same factor would be associated with a decrease in hedonic ratings. For example, CC beers M and O had relatively high intensities of rotten putrid, DMS, yeasty and grainy odours. These beers also had positive factor scores on odour factor one and were therefore associated with the positive pole of this factor (Table 52). Since these beers had the lowest mean scores on the whole scale, the positive pole of the factor was associated with a decrease in preference as shown by a negative β coefficient. Conversely, BC beers A_1, A_2 and C had relatively high intensities of sweet, caramel toffee and floral odour, and therefore had negative factor scores on odour factor one. These beers were therefore associated with the negative pole of this factor (Table 52). Since these beers had the highest mean scores on the whole scale (Table 52), the negative pole was associated with increased preference as shown by the negative β coefficient. The directions of each factor pole are shown in Table 53(a) for odours, 53(b) for flavour-in-mouth and 53(c) for aftertaste.(see p. 164).The multiple R^2 indicated that an interpretation could be made from the odour and aftertaste equations (Tables 53(a) and (c)). It was observed however, that the F-to enter ratios for the last factors taken into the equations were not always significant ($p \leq 0.05$). This was probably due to the forced entry

Table 53(a) Results of stepwise multiple regression analysis of odour factor scores (x) vs. mean hedonic scores (y)

(i) whole scale (y_1)

Odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	−0.475	25.4
3	fruity citrus, sour / oxidised stale	+0.627	33.5
4	malty, fruity other, caramel toffee / herbal, hops	+0.586	31.3
6	— / onions garlic, burnt rubber	−0.183	9.8
Multiple R^2 = 67.9%			

(ii) like scale (y_2)

Odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	−0.406	15.1
3	oxidised stale / fruity citrus, sour	−0.543	20.2
4	herbal, hops / malty, fruity other, caramel toffee	−0.998	37.1
6	onions garlic, burnt rubber / —	+0.741	27.6
Multiple R^2 = 65.9%			

(iii) dislike scale (y_3)

Odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	−0.330	15.5
3	fruity citrus, sour / oxidised stale	+0.650	30.5
4	malty, fruity other, caramel toffee / herbal, hops	+0.779	36.6
6	— / onions garlic, burnt rubber	−0.369	17.3
Multiple R^2 = 86.4%			

Table 53(b) Results of stepwise multiple regression analysis of flavour-in-mouth factor scores (x) vs. mean hedonic scores (y)

(i) whole scale (y_1)

Flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	caramel toffee, sweet / floral, herbal	−0.588	73.1
6	sweet, CO_2 tingle / salty, bitterness	−0.216	26.9
Multiple R^2 = 55.8%			

(ii) like scale (y_2)

Flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	floral, herbal / caramel toffee, sweet	+0.178	51.6
6	sweet, CO_2 tingle / salty, bitterness	−0.167	48.4
Multiple R^2 = 2.1%			

(iii) dislike scale (y_3)

Flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	caramel toffee, sweet / floral, herbal	−0.449	79.6
6	sweet, CO_2 tingle / salty, bitterness	−0.115	20.4
Multiple R^2 = 28.2%			

Table 53(c) Results of multiple regression analysis of aftertaste factor scores (x) vs. mean hedonic scores (y)

(i) whole scale (y_1)

Aftertaste factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	−0.244	19.0
5	sour / herbal, hops, floral	−0.555	47.1
6	spicy / mouthdrying, fruity citrus	−0.400	33.9
Multiple R^2 = 92.9%			

(ii) like scale (y_2)

Aftertaste factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	−0.216	12.4
5	herbal, hops, floral / sour	+1.017	58.5
6	spicy / mouthdrying, fruity citrus	−0.506	29.1
Multiple R^2 = 78.2%			

(iii) dislike scale (y_3)

Aftertaste factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	−0.034	3.4
5	sour / herbal, hops, floral	−0.691	69.0
6	spicy / mouthdrying, fruity citrus	−0.276	27.6
Multiple R^2 = 73.6%			

of all factors into the equation. These results may still be used to give an indication of the relative contribution of each factor to the variation in hedonic response. In the analysis of the whole scale (y_1) for odour (Table 53(a)(i)), the poles associated with BC beers corresponded to an increased preference in factor one and four. In these factors odour qualities sweet, caramel toffee, malty, floral and fruity other therefore corresponded to an increase in preference while rotten putrid, DMS, yeasty and grainy (essentially the sulphidic odour qualities) and herbal, hops odours were associated with decreases in hedonic ratings. In odour factor three, the pole associated with CC beers corresponded to an increase in hedonic ratings, with fruity citrus and sour sharp acidic odour being associated with increases in preference, and oxidised stale with decreases. Odour factor six shows that the sulphidic odour qualities, i.e. onions garlic and burnt rubber, correspond to decreases in hedonic ratings. Overall therefore, malty, sweet, caramel toffee, floral, fruity other and sharp acidic sour odour qualities were associated with increases in preference while sulphidic and hop associated odour qualities were related to decreases in hedonic ratings. This direction of the bipolar factors was maintained on the dislike scale (Table 53(a)(iii)) although the relative contribution of the sulphidic odour qualities in odour factor six was increased. On the like scale (Table 53(a)(ii)) the direction of three factors was changed and the relative contribution of each factor altered substantially. Odour factor four clearly becomes the most dominant factor in this analysis with herbal hops odour now corresponding with increased preference. The relative contribution of factor six was increased with the sulphidic qualities corresponding to an increase in preference. Although the pole associated with BC beers in odour factor one still corresponded to an increase in hedonic ratings, the relative contribution had decreased dramatically.

Although the multiple R^2 values for flavour-in-mouth were low, particularly on the divided scales, a general view of the direction and

contribution of the qualities in relation to preferences can be given. Throughout the analysis of the three scales, the relationship between caramel toffee, sweet and hop associated qualities (flavour-in-mouth factor four) dominated the equation, with caramel toffee and sweet corresponding to an increase in preference on the whole and dislike scales, and hop associated qualities corresponding to an increase on the like scale. This reversal of direction of factors on the like scale duplicates that already shown on the like scale by odour factor four (Table 53(a)(ii)). Sweet and CO_2 tingle (both qualities with higher intensities in BC beers) in flavour-in-mouth factor six was always associated with an increase in preference.

In the analysis of aftertaste, factor five accounts for the greatest part of the variation in preference throughout the equations. Table 53(c) shows that hop associated qualities are represented on the negative pole of this factor. As with other factors on which hop associated qualities are dominant, there is a change of direction on the like scale (Table 53(c)(ii)).Factor six accounts for the second largest part of the variation on all three scales with spicy aftertaste (a quality with higher intensity in BC beers) consistently corresponding to an increase in preference,and mouthdrying and fruity citrus corresponding to a decrease.

Once again,division of the hedonic scale shows a change in direction of certain independent variables which could be due to the bimodal distribution of preference ratings. As in the previous regression analysis (page 144), in order to assess the effect of this bimodality the analysis was repeated with the exclusion of the beer showing the greatest bimodality (beer M), (see Table 54, p. 167).

The exclusion of beer M from the analysis of the whole scale (y_1) for odour did not change the direction of the bipolar factors contributing to the hedonic response. However, owing to the relatively high intensity of sulphidic qualities,onions garlic and burnt rubber,in beer O and the low hedonic score for this beer (Table 52 page162), the

Table 54(a) Results of stepwise multiple regression of odour factor scores (x) vs. mean hedonic scores (y) excluding beer M from the analysis

(i) whole scale (y_1)

odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	-0.368	16.0
3	fruity citrus, sour / oxidised stale	+0.780	33.9
4	malty, fruity other, caramel, toffee / herbal, hops	+0.798	34.6
6	/ onions garlic, burnt rubber	- 0.358	15.5
Multiple R^2 = 63.8%			

(ii) like scale (y_2)

odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	-0.542	20.1
3	oxidised stale / fruity citrus, sour	- 0.806	30.0
4	herbal, hops / malty, fruity other, caramel toffee	-1.167	43.2
6	/ onions garlic, burnt rubber	- 0.184	6.8
Multiple R^2 = 81.9%			

(iii) dislike scale (y_3)

odour factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
1	sweet, caramel toffee, floral / rotten putrid, DMS, yeasty, grainy	- 0.286	10.4
3	fruity citrus, sour / oxidised stale	+1.003	36.5
4	malty, fruity otner, caramel toffee / herbal, hops	+1.155	42.0
6	/ onions garlic, burnt rubber	- 0.304	11.1
Multiple R^2 = 67.3%			

Table 54(b) Results of stepwise multiple regression of flavour-in-mouth factor scores (x) vs. mean hedonic scores (y) excluding beer M from the analysis

(i) whole scale (y_1)

flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	caramel toffee, sweet / floral, herbal	- 0.757	79.4
6	sweet, CO_2 tingle / salty, bitterness	- 0.196	20.6
Multiple R^2 = 80.4%			

(ii) like scale (y_2)

flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	floral, herbal / caramel toffee, sweet	+0.388	47.6
6	sweet, CO_2 tingle / salty, bitterness	- 0.427	52.4
Multiple R^2 = 11.8%			

(iii) dislike scale (y_3)

flavour-in-mouth factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	caramel toffee, sweet / floral, herbal	-0.716	91.8
6	sweet, CO_2 tingle / salty, bitterness	-0.064	8.2
Multiple R^2 = 57.7%			

Table 54(c) Results of stepwise multiple regression of aftertaste factor scores (x) vs mean hedonic scores (y) excluding beer M from the analysis

(i) whole scale (y_1)

aftertaste factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	-0.361	31.3
5	sour / herbal, hops, floral	-0.240	20.8
6	spicy / mouthdrying, fruity citrus	-0.554	48.0
Multiple R^2 = 94.1%			

(ii) like scale (y_2)

aftertaste factor	qualities related to increase in preference / qualities related to decrease in preference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	-0.170	10.2
5	herbal, hops, floral / sour	+0.759	45.5
6	spicy / mouthdrying, fruity citrus	-0.740	44.3
Multiple R^2 = 54.0%			

(iii) dislike scale (y_3)

aftertaste factor	qualities related to increase inpreference / qualities related to decrease inpreference	β coefficient	% contribution to variation
4	clean, caramel toffee / mouthcoating, bitterness	-0.274	27.8
5	sour / herbal, hops, floral	-0.150	15.2
6	spicy / mouthdrying, fruity citrus	-0.560	56.9
Multiple R^2 = 70.1%			

relative contribution of factor six in the equation was increased. (This was also shown in the analysis of pre-selected odour qualities page 149). Similarly there was no change in the direction of the bipolar factors on the dislike scale (Table 54(a)(iii)) although there was some slight increase in the contribution of factors three and four to the variation in hedonic response. The greatest change occurred on the like scale where the direction of factor six was reversed and its contribution towards the explained variation in preferences decreased dramatically.

Exclusion of beer M from the analysis of flavour-in-mouth qualities increased the multiple R^2 dramatically on all scales (Table 54(b)) allowing some interpretation of the whole and dislike scales. On both these scales, the direction of both factors remained unchanged but the contribution of factor four increased. The relationship between caramel toffee, sweet and hop associated qualities therefore remains the dominant factor contributing to the variation in preference in these equations.

The direction of all factors in the analysis of the aftertaste data remained the same after exclusion of beer M, although the relative importance of factor five decreased across all scales, the contribution of factor six increased on the like and dislike scale and that of factor four increased on the whole and dislike scales. Exclusion of beer M therefore clearly led to an increase in the contribution to the variation in preference of aftertaste qualities associated with BC beers viz. clean, caramel toffee and spicy.

It may be concluded that the exclusion of beer M led to changes in the extent of contribution and even to a change in direction of the contribution of certain qualities to preference variation.

The results from these regression analyses collectively highlight three distinct effects:

The first concerns the dominance in the equations for odour factors of(a) two'caramel toffee associated' poles [in one instance

opposed to sulphidic aroma qualities (factor one) and in the other opposed to hop associated qualities (factor four), see page 52] and (b) a unipolar factor of sulphidic odour qualities. This result shows that the intensity of caramel toffee associated odour qualities, sulphidic odour qualities and hop associated odour qualities, correspond closely to variations in preference. The prominence of the caramel toffee associated qualities versus hop associated qualities is also shown in flavour-in-mouth equations. Similarly in the equations incorporating aftertaste factors, these qualities were again prominent although their relative contribution was often decreased with the exclusion of beer M. The relationship between caramel toffee associated qualities and hop associated qualities could contribute directly to the preferences for BC beers, already shown by trained assessors to possess greater intensities of the 'caramel toffee' associated qualities and lower intensities of sulphidic odours and hop associated qualities. Sulphidic odour qualities, particularly those in odour factor six also appear to be directly related to the bimodality of preferences for certain beers.

The second effect concerns the reversibility of the bipolar nature of odour factors 3 and 4, flavour-in-mouth factor 4 and aftertaste factor 5. Although a direct effect of bimodality in the hedonic data, this reversibility clearly shows that the relationship between hop associated qualities and caramel toffee associated qualities is of utmost importance at the extremes of the hedonic scale. In simple terms, when a beer is liked, prominence of hop associated qualities corresponds to an increased liking (Table 54(a)(ii), (b)(ii), (c)(ii)). Conversely, when a beer is disliked prominence of these same qualities corresponds to increased dislike (Table 54(a)(iii), (b)(iii), (c)(iii)). Therefore, while a prominence of caramel toffee associated qualities corresponds to fewer extreme hedonic responses for odour and flavour-in-mouth, (i.e. has a "neutralisation" effect, since these qualities predominated in beers scored mainly in the neutral region, especially BC beers), a prominence of hop

associated qualities in a beer encouraged both extreme like and extreme dislike for any particular beer. Such information could be of crucial importance to brewers since a product with high hop associated qualities could only succeed if the correct target market were reached.

The third effect demonstrates the influence of a bimodal distribution of hedonic responses on regression analysis. Since data of this type are non-parametric, it is not surprising that some anomalies occur when such a method of analysis is applied. If the analysis had been restricted to the whole scale, this effect could have been overlooked and results misinterpreted. Even after dividing the scale, the direction of contribution of the sulphidic odours in factor six on the like scale, (Table 53(a)(ii)), itself a direct result of the bimodal distribution of beer M, could have been misinterpreted. It is therefore proposed that regression analysis can provide a useful indication of reasons for trends in preference, provided results are critically examined in the light of a thorough investigation of the data used. In this research other pieces of information provided useful indications of possible anomalies occurring during regression analysis, for example: (i) the hedonic index of the sulphidic odour class (page 125) indicated that these qualities were usually only associated with low preference ratings (ii) the distributions of hedonic scores (page 91) revealed the inadequacy of the mean in the case of beers with bimodal distributions.

Comparison of the results of this regression analysis with that performed on frequency of use by consumers of pre-selected qualities (page 144) reveals similarities in the case of odour qualities but considerable disparity in the case of taste qualities. Analysis of pre-selected odour qualities revealed that caramel toffee malty and rotten contributed most consistently to the equations (page 151) and this compares well with the dominance of caramel toffee and sulphidic qualities in this present analysis (page 168). The prominance of sweet

and fizzy tastes in the analysis of pre-selected taste qualities is not shown to any great extent by the present analysis of factor scores for flavour-in-mouth and aftertaste.

Although the relationship of sweet and CO_2 tingle in flavour-in-mouth factor six was consistently associated with increases in preference, the contribution of these flavour qualities was overshadowed by that of the caramel toffee, sweet versus hop associated dimensions in flavour-in-mouth factor four. Neither sweet nor CO_2 tingle qualities appeared as prominent qualities in the aftertaste factors; hops associated qualities of CC beers, and caramel toffee, clean and spicy qualities of BC beers dominated the equations.

A possible explanation for this disparity is the apparent lack of appreciation by the consumer of the relative importance of the caramel toffee v. hop associated relationship indicated by the regression of factor scores for taste. Thus data from a relatively objective sensory assessment, by the trained panel, of the intensities of the caramel toffee-hop associated complex showed a close association with variations in preference. However, data from a relatively subjective sensory assessment by consumers placed greater emphasis on other less subtle and perhaps more easily definable qualities such as fizzy mouthfeel and the sweet, bitter and sharp sour basic tastes. It is thought possible that the importance to the consumer of the caramel toffee-hops associated flavour complex could increase during a prolonged contact with the beer, such as that experienced during a drinking rather than a tasting situation. This is supported by the results from the assessment of odour which showed good agreement in the appreciation of the importance of caramel toffee odour in the case of both regression analyses and which would have been affected less by the enforced 'tasting environment'. This will be discussed on page 173.

Examples of the attempts of other workers to analyse preference data using regression techniques will now be critically discussed in the

light of these results. The use of multivariate methods to analyse relationships between sensory descriptive data and preference data include a study of red wine quality,[133] consumer evaluation of orange beverages,[131] prediction of hedonic ratings of carrots,[72] prediction of hedonic ratings of rice,[73] acceptability of meat;[74] acceptability of fish minces and fish fingers,[75] and studies of the quality of frozen fish.[134,135] Throughout these published works, no account appears to have been taken of the distributions of hedonic responses from which mean hedonic scores, used as dependent variables, were taken. In only three of the studies[72-74] were separate panels of trained assessors and consumers used to obtain descriptive data and preference data respectively. In the first study, five trained assessors were used to investigate textural qualities of carrots which were then assessed for preference by forty-two consumers.[72] In the second study, twenty types of rice were assessed by six trained assessors for fifteen sensory qualities; one hundred consumers subsequently assessed the samples for preference.[73] Only a limited number of selected texture qualities were regressed against hedonic means, no attempt having been made to condense the qualities prior to the regression analysis. Use of factor scores, as demonstrated in this current research, offers a solution to the problem of data reduction which is necessary to eliminate or reduce inter-relations among the independent variables. The inter-relations among variables were taken into account in the third study, in which thirteen meat products were assessed by forty trained assessors for eleven sensory qualities;[74] three hundred and ninety consumers subsequently assessed the samples for preference and acceptability. The eleven sensory qualities were reduced to three components using principal components analysis and these components were used to predict acceptability.[74]

Lack of details of the frequency distribution of preference data in published works prevents any conclusive discussion of the importance of bimodal distributions. Kuen and Day have shown however, that knowledge of reasons for bimodality allow a small specialised

market to be satisfied, thereby increasing sales over the 'middle of the road' product which satisfied no one group of consumers to the same extent.[113] It has been shown in this project how hop-associated qualities were closely related to extremes of preference (page 169). Since these qualities were shown by the trained panel to have a significantly greater intensity in CC beers, this could explain the success of this beer type in its traditionally restricted areas of distribution. In such a restricted market, in order to have continued success, a product would have to exhibit some discernible difference which appealed to a significant proportion of that market. The national BC beers analysed by our trained panel were shown to exhibit relatively few prominent qualities and would therefore be unable to offer such differences. Thus, provided the proportion of consumers who liked hop qualities was sufficiently large within any given distribution area, the success of such a CC beer would be guaranteed.

During discussion of the disparity between results from the two series of regression analyses performed on taste data during this project, (page 170) it was suggested that the consumers' perception of certain flavour qualities could have been affected by the 'tasting environment'. Other works have observed a disparity between results from tasting and drinking environments.[78,135] Although it is possible that assessments made by consumers in a drinking situation could reveal useful information, it is thought that the controlled tasting environment is preferable for an assessment of the consumers' ability to interpret perceived flavour sensations.

SUMMARY AND CONCLUSIONS

This project was designed to test three basic aims (page 17). The conclusions reached after analysis of the results will be presented in a manner which will show the degree to which each of these aims has been met.

Part I of this project was concerned with the objective definition and quantitifcation of flavour differences, as perceived by the human senses, between BC and CC bitter beer types. Trained assessors showed that the 19 beers analysed differed significantly ($p \leq 0.05$) in terms of only 14 flavour qualities, i.e.

burnt roasted (odour)
onions garlic (odour)
rotten putrid (odour)
burnt rubber (odour)
floral fragrant (odour)
sweet (odour)
hops (odour)
fruity (odour)
malty (odour)
bitterness immediate (flavour-in-mouth)
burnt rubber (aftertaste)
hops (aftertaste)
resinous woody (aftertaste)
bitterness (aftertaste)

However, the two beer types were shown to differ significantly ($p \leq 0.05$) in terms of 22 flavour qualities, i.e.

yeasty (odour)
hops (odour)
sour acidic sharp (odour)
caramel toffee (odour)
mouthcoating (flavour-in-mouth)
malty (flavour-in-mouth)
bitterness immediate (flavour-in-mouth)
sweet (flavour-in-mouth)

sour acidic sharp (flavour-in-mouth)
caramel toffee (flavour-in-mouth)
floral fragrant (flavour-in-mouth)
mouthdrying (flavour-in-mouth)
phenolic (flavour-in-mouth)
CO_2 tingle (flavour-in-mouth)
herbal (aftertaste)
mouthdrying (aftertaste)
clean (aftertaste)
floral fragrant (aftertaste)
hops (aftertaste)
bitterness (aftertaste)
sweet (aftertaste)
mouthcoating (aftertaste)

Thus more significant differences existed between the flavour of these beers grouped according to beer type than existed between the individual beers. It was also shown that the flavour of individual CC beers was more varied than that of individual BC beers and was associated with certain specific and distinguishing flavour qualities, as described below.

By means of factor analysis, the odour data were reduced to 9 groups of related qualities, explaining 64% of the variance between

samples; similarly flavour-in-mouth data were reduced to 11 factors explaining 66.5% of the variance and aftertaste data were reduced to 10 factors explaining 70% of the variance. Subsequent nested ANOVA on the factor scores indicated that the individual beers differed significantly in terms of 3 odour factors, and 2 aftertaste factors, while the beer types differed significantly in terms of 4 odour factors, 2 flavour-in-mouth factors and 3 aftertaste factors. A generic description of the flavour of the two beer types showed that 34 of the 96 qualities analysed contributed to flavour differences between them. These are summarised as follows:

Flavour qualities	CC > BC		BC > CC
ODOUR	rotten putrid DMS yeasty grainy fruity citrus	sour acidic sharp herbal hops onions garlic burnt rubber	sweet caramel toffee floral fragrant oxidised state malty fruity other
FLAVOUR-IN-MOUTH	floral fragrant herbal	salty bitter	caramel toffee sweet CO_2 tingle
AFTERTASTE	mouthcoating bitter herbal floral fragrant	hops sour acidic sharp mouthdrying fruity citrus	clean caramel toffee spicy

It was observed that 3 major groups of flavour qualities consistently contributed to differences in flavour between the two beer types, i.e. caramel toffee associated qualities (BC > CC)

hops associated qualities (CC > BC)

sulphidic qualities (CC > BC)

The occurrence of caramel toffee qualities was frequently negatively correlated with that of either hops or sulphidic qualities, and although the prominence of sulphidic qualities was restricted to odour assessments, hops and caramel toffee qualities persisted as odour, flavour-in-mouth and aftertaste sensations.

From these results it is possible to conclude that a number of flavour differences between BC and CC bitter beer types were defined and quantified, thereby meeting the first aim of this research project.

Part II of this project was concerned with determining any consumer preferences for the flavour of beers selected to represent the two beer types. The consumer sample of 207 regular bitter beer drinkers showed a significant preference for both the odour and taste of BC beers - a preference which could not be explained either in terms of the demographic structure or the drinking habits of the consumer sample. Division of the consumer sample according to the type of beer regularly consumed, revealed a stronger preference for the odour and taste of BC beers by regular drinkers of this beer type, although the overall preference for BC beers was maintained for all sub-divisions of the sample. In the case of certain CC beers, particularly beer M, the distribution of preference data was bimodal, indicating a concentration of extreme likes and extreme dislikes for such beers. The departure of these distribution curves from normality could have invalidated the use of the parametric ANOVA used. From a comparison of parametric and non-parametric ANOVA of the preference data, it was shown that the robustness inherent in the parametric procedure was adequate to prevent any serious distortion of results using parametric methods on these particular data.

A comparison of the observed significant flavour differences (analysed by the trained panel) between the beers selected for the consumer survey, and variations in preference for these beers, revealed similar trends in both odour and taste data. This suggested that preferences could be based on definable flavour differences between the beers.

By classifying the odour and taste terms used by the consumer as reasons for preference, 76% (1791) of odour terms were condensed into 40 odour classes, and 77% (2434) of taste terms were condensed into 40

taste classes. Correlation analysis of these odour and taste classes with the corresponding flavour qualities analysed in the same beers by the trained panel showed that significant correlations were found for 5 odour qualities, i.e.

malty	burnt rubber
rotten putrid	sweet
onions garlic	

5 flavour-in-mouth qualities, i.e.

hops	sour acid sharp
rotten putrid	CO_2 tingle
sweet	

6 aftertaste qualities, i.e.

floral fragrant	burnt roasted
hops	rotten putrid
herbal	burnt rubber

Frequency of use of odour and taste classes for the two beer types showed that alcoholic, fruity, hops, sulphidic, papery, acidic and body fullness classes were used more often to explain hedonic responses for the odour of CC beers, while malty, caramel, sweet and lack of odour character were used more often for BC beers. As far as taste was concerned, floral, hops, malty, burnt, sulphidic, papery, bitterness, low CO_2 and body watery classes were used more for CC beers and fruity, caramel, sweet, high CO_2, body fullness and lack of taste character classes were used more for BC beers. In both cases this result compared well with the generic description of flavour differences determined by the trained panel.

Analysis of the relative use of odour and taste classes across the hedonic scale showed that certain classes (e.g. sulphidic odour and taste, papery odour and taste, and acidic odour and taste) were used to a greater extent over the dislike end of the hedonic scale, whereas other classes (e.g. hops odour, body fullness odour and taste, malty and bitter tastes) were used to a greater extent over the like end of the hedonic scale. A "hedonic index" for each flavour quality was proposed; this allowed the relative use of different flavour classes to be compared and reasons for the preference of each of the selected beers to be stated in

terms of the consumers' own flavour descriptions.

Correlation analysis of the frequency of use by consumers of 7 pre-selected odour qualities and 7 pre-selected taste qualities with the intensities of the corresponding flavour qualities determined by the trained panel, showed significant correlations for 4 pre-selected odour qualities, i.e.

sweet	caramel toffee malty
fruity	rotten

and 6 pre-selected taste qualities, i.e.

sweet	caramel toffee malty
like flowers	bitter
sharp sour	smooth

As far as the two beer types were concerned, fruity, like flowers, sharp sour, burnt and rotten odour were used more often for CC beers while sweet and caramel toffee malty odours were used more often for BC beers. In the case of taste, like flowers, sharp sour, bitter and smooth were used more frequently for CC beers while sweet, caramel toffee malty and fizzy were used more often for BC beers. This result also compared favourably with the generic description of flavour differences determined by the trained panel.

Factor analysis of the frequency of use by consumers of the pre-selected odour and taste qualities showed similar inter-relationships between qualities as described for the trained assessors. Both factor analyses showed negative correlation between sweet, caramel toffee odours and rotten odour, and also between caramel toffee malty odours and hop (like flowers) odours. Similarly with regard to taste, a negative correlation was shown between bitter and fizzy and also between bitter and caramel toffee tastes by both sets of data. This indicated a similarity in perception of certain odour and taste qualities by both consumers and trained assessors and added further support to the ability of the consumer to perceive and describe prominent qualities in beer.

Stepwise multiple regression analysis provided a satisfactory explanation of the variation in preference for odour and taste of the selected beers in terms of frequency of use by consumers of pre-selected

flavour qualities. The effect of bimodality on the analyses was assessed by separate analyses of the like and dislike sections of the hedonic scale; exclusion of the beer with the greatest bimodality (beer M) gave an example of the effect of this phenomenon on this form of analysis. It was shown that caramel toffee malty and rotten were the odours which contributed most to the explanation of preference variations, caramel toffee malty (prominent in BC beers) corresponding to increases in preference and rotten corresponding to decreases in preference. With regard to taste, sweet and fizzy (both prominent in BC beers) contributed most to the variation in preferences, both corresponding to increases in preferences.

Ranking by consumers of the pre-selected odour qualities showed caramel toffee malty to be significantly more important and rotten odour significantly less important than other odour qualities ($p \leq 0.05$). In the case of taste both bitter and smooth were significantly more important and both fizzy and like flowers significantly less important than the others. The relative levels of importance attached to caramel toffee malty and rotten odours confirm the significance of these qualities in beer. This result also confirmed the importance in the mind of the consumer, of a bitter taste in beer.

From these collective results it may be concluded that a significant preference existed in this consumer sample for the odour and taste of BC beers; furthermore, it may be concluded that these consumers showed a significant ability to provide reasons for this preference thus meeting the second aim of this project.

A second stepwise multiple regression analysis also provided a satisfactory explanation of the variation in preference for odour and taste of the selected beers in terms of the objectively determined flavour differences from Part I of this project. In this instance, caramel toffee associated odour qualities contributed considerably to the

explanation of the variation in odour preferences, and additional information on the inter-relationships of these qualities, with both hops and sulphidic odour qualities, was obtained. Allowing for bimodality as before, by sub-division of the hedonic scale and exclusion of CC beer M, it was shown that hop associated odour qualities corresponded to extreme hedonic responses of like and dislike whereas caramel toffee odour qualities corresponded to a relatively neutral response. Sulphidic odour qualities were also prominent in the analysis and were more usually associated with decreases in preference. The relationship between hops associated qualities and caramel toffee qualities was also shown when flavour-in-mouth qualities were regressed with taste preferences; hop qualities also remained associated with extremes of preference when after-taste qualities were regressed with taste qualities. While explanations of trends in odour preference (using data from consumers and those from the trained panel) both confirmed the importance of caramel toffee associated and sulphidic odour qualities, there was some disparity in the explanations for trends in taste preferences. It was proposed that this disparity was due to the inability of the consumer to fully assess the complex relationship between caramel toffee and hops qualities within the limitations of a tasting environment.

It is concluded that the satisfactory explanation of variations in preference in terms of objectively determined flavour difference meets the third and final aim of this research project.

As a consequence of the conclusions from this project, a number of observations may be made. Firstly, the considerable differences found here between the two beer types in terms of definable flavour qualities, show the differences of sweetness, bitterness and the undefined blandness stated by the Foods Standard Committee to be inadequate. Secondly, the occurrence of two groups of flavour qualities, hops and caramel toffee associated qualities, appeared to be related to the bimodality observed in the odour and taste preferences of certain beers. If, as these results suggest, hop qualities are responsible for extreme likes and dislikes of certain beers, this information could be of use to the brewer, especially in a limited market, such as that which exists for many CC beers. Thirdly, throughout this project three groups of associated flavour qualities have shown themselves to be important, both in the differentiation of beer types by the trained assessors and in the explanation of variations in preference using descriptive data from the consumers. This result suggests that monitoring the perceived levels of caramel toffee associated, hop associated and sulphidic qualities, would give the brewer a useful indication of the potential success of the product in a given market.

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